U.S. Department of Justice
Office of Justice Programs
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REPORT TO CONGRESS

Needs Assessment of Forensic Laboratories and Medical Examiner/Coroner Offices

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I. Executive Summary

The Justice for All Reauthorization Act of 2016 (JFARA) mandated a needs assessment of forensic laboratories, which included an examination of workload, backlog,[1] personnel, and equipment needs for both public crime laboratories and medical examiner and coroner (ME/C) offices. In conducting this needs assessment, the U.S. Department of Justice (DOJ) made efforts to integrate literature, stakeholder comments, and feedback from listening sessions in an extensive examination of the forensic science components currently operating in the United States. This community has seen many advances and promising practices in the past decade, some of which are featured in this report.

One of the Department's priorities for the forensic sciences is facilitating coordination and collaboration on forensic science within the Department, across the federal government, and with state, local, and tribal entities. In conducting this needs assessment, the Department identified the importance of strengthening these types of efforts through the increased use and institutionalization of systems-based approaches. A systems-based approach involves coordination and collaboration among forensic laboratories, ME/C offices, law enforcement, legal professionals, and other stakeholders, from the crime scene to the courtroom. Using a systems-based approach as an organizing and unifying theme, this report touches upon the forensic science system as a whole, from the education and training required for current and future personnel, to workload and infrastructure needs, to the process of bringing a case to trial from both the defense and prosecution perspectives.

Further, this needs assessment compiles demonstrative evidence of how the field adapts to advancements in technology, changes in the volume and types of forensic evidence, and the evolving needs of the justice system, with particular focus on sexual assault evidence backlogs and the opioid crisis. Forensic laboratories and ME/C offices are constantly working to address the needs of the field, balancing operations priorities to meet stakeholder requests, while introducing innovative solutions to solve emerging criminal justice questions.

This needs assessment is unique in that it addresses different components of the system, which has not been done previously. The Department, in coordination with the National

[1] The Bureau of Justice Statistics' Census of Publicly Funded Forensic Crime Laboratories defines a backlogged request as a request that has been submitted to a specialized area of the crime laboratory, and it was not examined and reported to the submitting agency within 30 days of submission.

Institute of Justice (NIJ) Office of Investigative and Forensic Sciences (OIFS), took a mixed-methods analysis approach, combining available quantitative data from sources like Project FORESIGHT and various programs and projects of NIJ and other offices and bureaus of the Office of Justice Programs (OJP). These data include previous needs assessments, surveys, and assessment data from a variety of funded projects.

To assess those topics not easily captured by quantitative metrics, the Department conducted targeted listening sessions with groups of stakeholders and subject matter experts from varied forensic disciplines and across the criminal justice system during the information collection and literature search phases of this assessment. Over the course of approximately one year, the Department held listening sessions with representatives from the International Association for Identification (IAI), Society of Forensic Toxicologists (SOFT), American Board of Forensic Toxicology (ABFT), International Association of Chiefs of Police (IACP), National Sheriffs' Association (NSA), Association of State Criminal Investigative Agencies (ASCIA), Major Cities Chiefs Association (MCCA), American Society of Crime Laboratory Directors (ASCLD), National Association of Medical Examiners (NAME), International Association of Coroners and Medical Examiners (IACME), American Board of Medicolegal Death Investigators (ABMDI), and the Scientific Working Group on Digital Evidence (SWGDE), as well as representatives from academic forensic science degree programs, prosecutors, defense attorneys, and judges. In addition to the listening sessions, informal discussions were held with several other subject matter experts and stakeholder groups, such as the International Association of Forensic Nurses (IAFN), Federal Law Enforcement Training Centers (FLETC), and subject matter experts with expertise in serving tribal communities. The Department also relied on internal subject matter experts at the National Advocacy Center (NAC), Executive Office for U.S. Attorneys (EOUSA), the Federal Bureau of Investigation's (FBI) Indian Country Crimes Unit (ICCU), as well as OJP's Office for Victims of Crime (OVC), Office of Juvenile Justice and Delinquency Prevention (OJJDP), Bureau of Justice Assistance (BJA), Bureau of Justice Statistics (BJS), and NIJ's Office of Research and Evaluation (ORE) and Office of Science and Technology (OST), to name a few.

This report does not make specific policy recommendations, but it presents promising practices and evidence-based practices to address needs expressed during this assessment, provides guidance to readers interested in translating these practices in their operations, and offers solutions with measurable performance indicators and outcomes. The most critical information related to each topic in the report is presented in bullet points at the beginning of each section, divided into Needs, Challenges, and Promising Practices. The key needs, challenges, and promising practices highlighted in this report are presented below.

Through this assessment, the Department has embraced the opportunity to hear from the forensic community regarding its needs, and the Department has decided to establish a formal working group to further this effort. In 2018, NIJ established the Forensic Laboratory Needs Technology Working Group (FLN-TWG) with the mission of providing objective and independent knowledge, data, information, and expertise to inform NIJ's decision-making process on the operational and implementation needs of federal, state, local, and tribal practitioners relating to forensic technology.

This standing working group is composed of approximately 20 members, which include state and local forensic crime laboratory directors, senior laboratory managers, and academic forensic researchers from across the country, representing large and small, urban and rural facilities. The FLN-TWG, which uses a model of practitioners supported

by researchers, will also ensure that forensic research is relevant and responsive to law enforcement technology needs and will produce actionable results.

The findings in this report incorporate the opinions of the forensic science community, including viewpoints collected from listening session participants; these findings and views are not necessarily the views of the U.S. Department of Justice. Any discussions of products and manufacturers in this report are for informational purposes only and do not constitute product approval or endorsement by the U.S. Department of Justice.

Key Findings

Needs:

- *Institutionalization of systems-based communications between forensic science service providers, their customers, and other stakeholders to better understand and calibrate expectations, track the status of a case as it is processed through the system, and inform evidence submissions, testing priorities, and laboratory decision-making.* This includes systems-based, collaborative training opportunities. There are limited opportunities for interdisciplinary training and coordination, and there is a need for better training opportunities overall.

- *Sufficient and consistent funding and strategic planning to process increasing amounts of forensic evidence and to address fluctuations in evidence submissions driven by the supply of and demand for forensic services.* A 2017 analysis of a subset of publicly funded, accredited laboratories' workloads and expenditures estimated that forensic laboratories nationwide would require an additional $640 million annually to reach an optimal balance of incoming laboratory requests and casework reported (workload inputs and outputs) and maintain the ideal balance of capital investments and personnel.

- *Sufficient and consistent funding and strategic planning to address the impact of the opioid crisis on forensic laboratories and medical examiner and coroner offices.* An analysis of a subset of publicly funded, accredited laboratories estimated that forensic laboratory expenditures specifically as a result of the opioid crisis totaled $270 million in 2015. Laboratory expenditures for the analysis of drugs and controlled substances increased by 37% in that year, and expenditures for toxicology analysis (including antemortem and postmortem toxicology) increased by 25%, compared to typical laboratory growth in expenditures of less than 3% per year for the past decade. Between 2011 and 2017, there were substantial increases in the turnaround times and backlogs for drug/controlled substance and toxicology casework.

- *Sufficient and consistent funding and strategic planning to address medical examiner and coroner workforce and workload challenges.* Variability in medical examiner and coroner resources and access to qualified medicolegal death investigation services can result in the inequitable application of death investigations.

- *Sufficient and consistent funding for forensic practitioner training.* Virtually all new employees, whether experienced analysts or recent graduates, require significant training to become eligible for casework. Furthermore, in order to maintain proficiencies, individual certifications, and facility accreditations, forensic personnel must frequently undergo continuing education and professional development. Medicolegal death investigation personnel also have continuing medical education requirements for maintaining their licenses and certifications.

- *Improvement in the personnel pipeline from education through hiring and training, particularly in disciplines that are facing critical personnel shortages.* Analysis of a subset of publicly funded, accredited laboratories' data through 2017 estimated that county, city, and state laboratories nationwide would need more than 900 additional full-time employees to efficiently address current caseloads. There is a particular need to strengthen the medical examiner and coroner workforce by addressing the critical shortage of board-certified forensic pathologists (BCFPs) and by bolstering the other positions that support the BCFP workload (e.g., medicolegal death investigators, autopsy technicians, and forensic photographers). There are currently only 400-500 physicians who practice forensic pathology full time, less than half of the total estimated need for 1,100-1,200 forensic pathologists in the United States. The true number of BCFPs needed is likely much higher, due to the surge in drug overdose deaths related to the opioid crisis, as there were over 70,000 drug overdose deaths in 2017. These personnel needs include increased training, continuous education, and staffing resources.

- *Sufficient supply of graduates from academic programs who are prepared to seek and obtain employment in forensic science fields upon program completion.* While graduates of forensic science programs tend to be prepared with scientific skills, they may lack the practical experience and critical thinking skills necessary to be ready to provide immediate support in the laboratory upon hiring. There is a need to bridge the gap between the goals of the academic programs and those of the forensic laboratories. The hiring process also typically requires that applicants pass a background check (including drug testing) as a condition of employment.

- *Continued efforts to strengthen quality assurance measures, limit preventable nonconformities, and maintain a healthy workforce in the forensic sciences.* These efforts can include supporting accreditation processes and hiring dedicated laboratory staff, such as a quality manager.

- *Efforts to maintain a resilient forensic workforce.* Efforts can include developing resources to address workforce stress and vicarious trauma associated with the forensic work environment.

Challenges:

- Collaboration and communication between forensic practitioners and their various stakeholders using systems-based approaches are currently impaired at several points. Stakeholders indicated that coordination can be improved to enhance evidence collection and preservation, inform requests for testing, and notify personnel who are subpoenaed to testify in a case that is later dismissed or results in a plea bargain. Better and normalized communication during these crucial points can avoid unnecessary testing or diversions of forensic laboratory resources.

- Increased workloads, combined with the increased complexities of forensic evidence and associated testing requirements, contribute to casework backlogs. Workloads depend not only on the number of cases submitted, but also on the number of items and samples tested. Current data indicate increasing backlogs in digital and multimedia evidence, drugs/controlled substances, and toxicology. Increasing workloads for medicolegal death investigations and forensic autopsies that surpass the limits set by professional standards can threaten the accreditation status for those medical examiner and coroner offices that are accredited. Implementation of new technologies may contribute to short-term backlogs but result in longer-term efficiencies and provide results with more sensitivity and specificity.

- The physical capacity, infrastructure, and information technology for many forensic laboratories and ME/C offices are already maximized to their limits and/or outdated.
- Recruiting, hiring, and training are time and resource intensive, and the hiring for civilian forensic practitioner positions may compete with the hiring for law enforcement sworn positions. Background investigation requirements, including polygraph examinations, dramatically reduce the pool of qualified applicants. Once new positions are funded and filled, it can still take anywhere from three months to several years for newly hired personnel to become proficient to perform casework and begin contributing to backlog reduction. Further, competition from the private sector makes recruitment and retention challenging in areas such as forensic pathology and digital and multimedia investigations.
- Funding for training is typically only 0.5% of forensic laboratories' operating budgets. Furthermore, training typically means time away from the laboratory bench, resulting in a decrease in casework productivity.
- While ME/C systems are burdened by the opioid crisis, their workload issues are compounded by inconsistent staffing and limited budgets, resources, and supplies that make it difficult to effectively and efficiently perform death investigations across all ME/C systems and jurisdiction sizes.
- With the exception of federal funding to support capacity enhancement and backlog reduction of DNA analysis at state and local forensic laboratories, dedicated funding is not available for all other forensic disciplines practiced by forensic laboratories and ME/C offices.
- There is a lack of dedicated funding for forensic science research, development, and evaluations. While NIJ and other federal agencies contribute to the national forensic science research infrastructure, agencies routinely rely on programmatic funds to support forensic science research efforts.
- Increasing workloads, backlogs, and stressful work environments take a toll on the forensic workforce. While resources are available to law enforcement and other industries to address stress and vicarious trauma, few tools have been developed specifically for forensic personnel.

Promising Practices:

- Systems-based approaches to making informed decisions regarding forensic evidence submissions and requests for analysis.
- Implementation of innovative mechanisms to better utilize current resources to increase efficiency, reduce workload, and improve turnaround times.
- Collaborative efforts to encourage cost sharing and to help promote a systems-based approach.
- Enhancing the forensic employment pipeline by increasing exposure to practical experiences and expanding outreach, recruitment, and retention strategies.
- The availability of federal grant programs and resources for addressing various needs and challenges in the forensic sciences:

- Organizations can use various DOJ resources and funding opportunities, including those of NIJ and BJA, to successfully address laboratory efficiency and capacity challenges as well as multidisciplinary and systems-based approaches.

- Agencies can use NIJ's Paul Coverdell Forensic Science Improvement Grants program to purchase new technologies and equipment; address personnel, accreditation, education, certification, and training needs; and address challenges posed by the opioid crisis.

- Agencies can use DOJ resources to invest in infrastructure development, facility renovations, new technologies, and equipment.

- There are a variety of training programs available through federal partnerships, such as those offered by FLETC and BJA's Sexual Assault Kit Initiative, as well as continuing education opportunities through symposia, workshops, special events, and webinars, such as those offered by NIJ's Forensic Technology Center of Excellence.

II. Introduction

This report details the results of a national needs assessment of forensic science service providers conducted in 2017-2018. This needs assessment focused on the services provided by forensic laboratories, medical examiner and coroner (ME/C) offices, and other forensic science service providers through the lens of the interconnected relationship between forensic laboratories and the criminal justice system. As forensic analyses have expanded and become more sensitive, and as practitioners have established more evidence-based policies and capabilities, the broad demand for forensics has grown. Forensic laboratories and ME/C offices are constantly working to address the needs of the field, balancing operational priorities to meet stakeholder requests while introducing innovative solutions to solve emerging criminal justice questions. This needs assessment compiled demonstrative evidence of how the field is adapting to advancements in technology, the volume and types of forensic evidence, and the evolving needs of the justice system.

A. Guiding Legislation

The Justice for All Reauthorization Act of 2016 (JFARA) [1] called for a needs assessment of forensic laboratories. This mandate also charged the attorney general with overseeing a study and report to include the following required components (§16):

- Examine the status of current workload, backlog, personnel, equipment, and equipment needs of public crime laboratories and medical examiner and coroner offices
- Include an overview of academic forensic science resources and needs from a broad forensic science perspective, including nontraditional crime laboratory disciplines such as forensic anthropology, forensic entomology, and others as determined appropriate by the attorney general
- Provide Congress with a comprehensive view of the infrastructure, equipment, and personnel needs of the broad forensic science community in a publicly available report

The JFARA legislation guided the extensive work that led to this report, which builds on previous assessments of crime laboratories, [2-6] ME/C facilities and systems, [7-12] law enforcement, [13-14] forensic education, [15-17] and nontraditional disciplines. [18-22] Considering these previous reports, along with practitioner-led efforts to advance the forensic sciences and other initiatives to improve metrics in the forensic sciences, [23-26] we are at a point where the practice has advanced rapidly within the last decade, as have

the forensic data collection and analysis strategies, allowing for this report to be both more comprehensive and more targeted than its predecessors.

B. Background

In the past decade, the forensic sciences have evolved and progressed due to advancements in knowledge and technology and continued efforts to strengthen standardization and accreditation. Recent forensic science efforts include: the implementation of new techniques, such as DNA analysis that provides increased sensitivity to help determine when a number of individuals have contributed to a sample; research to better understand the value of physical evidence and the limits of scientific methods; the increased standardization of certain fields; the creation of practitioner-led organizations; the widespread implementation of policies designed to ensure quality practices; and the increase in and popularization of advanced forensic science academic programs. Within the federal government, the U.S. Department of Justice (DOJ), particularly the National Institute of Justice (NIJ) and the other component agencies within the Office of Justice Programs (OJP), has been at the forefront of advances in policy and practice within the forensic sciences.

Several other federal entities, including the National Institute of Standards and Technology (NIST) and the National Science Foundation (NSF), have contributed to the advancement of the forensic sciences as well. [27, 28] These advances occurred at the same time that reports and research — including a report by the National Research Council of the National Academies of Sciences (NAS), Engineering, and Medicine — were identifying a path forward for the forensic sciences. [29, 30] It is important to acknowledge the foundation provided by this and previous assessments of the field. The following reports and prior needs assessments have provided the foundation for this assessment and are reviewed in greater detail in Appendix A.

- The NAS *Strengthening Forensic Science in the United States: A Path Forward* (2009) [30]
- The NAS *Support for Forensic Science Research: Improving the Scientific Role of the National Institute of Justice* (2015) [31]
- The National Science Technology Council, Committee on Science, Subcommittee on Forensic Science — *Strengthening the Forensic Sciences* (2014) [32]
- The Bureau of Justice Statistics *Census of Publicly Funded Crime Laboratories* [3, 5, 33, 34]
- Individual states' needs assessments [35, 36]
- Project FORESIGHT data [37]

C. Methodology

This report adopted a mixed-methods analysis approach, combining available quantitative data from sources like Project FORESIGHT and data from various NIJ and other OJP programs and projects, to include previous needs assessments, surveys, and assessment data from a variety of funded projects. Additionally, to assess those topics not easily captured by quantitative metrics, targeted listening sessions were conducted with groups of stakeholders and subject matter experts from varied forensic disciplines and across the criminal justice

system. This approach was chosen because it permits a deep understanding and explanation of the current state of forensics in the United States, drawing out a variety of themes and subthemes.

Additional details on the methodology utilized in this needs assessment are provided in Appendix B of this report.

III. Personnel

Needs:

- Strengthening the personnel pipeline from education through recruitment, hiring, training, and retention, particularly for disciplines that are facing critical personnel shortages.
- Systems-based, collaborative training opportunities, including opportunities for collaboration and partnership between forensic service providers and universities on matching curriculum to employment needs, research and development, equipment sharing, and training opportunities.
- Funded, accessible, and available continuing education and professional development opportunities, especially in fields where these are required to maintain certifications.
- Resources to address workforce stress and vicarious trauma associated with the forensic science work environment.

Challenges:

- There is a delay between hiring and job readiness for all candidates. Even if qualified candidates can be identified and hired, it can still take anywhere from three months to several years for that individual to be fully trained and proficient for casework.
- There are particular challenges with hiring recent graduates, as scientific academic training may not match forensic laboratory needs or preferences.
- Funding for training is typically only 0.5% of laboratories' operating budgets.
- Personnel retention is challenging because private sector salaries and burdensome student loan debt, particularly in the areas of forensic pathology and digital analysis, can attract candidates away from public service.
- Background investigation requirements dramatically reduce qualified applicant pools.
- While resources are available to law enforcement and other industries to address stress and vicarious trauma, such tools have not yet been developed specifically for forensic personnel.
- Lack of funding for training, certification of personnel, and accreditation.

Promising Practices:

- Integrating background investigations into the academic application process or curriculum can assist individuals in selecting an appropriate career path and remove inappropriate candidates from the applicant pool.
- Internships provide students with real-world experience that increases job readiness, and research opportunities expand scientific skill sets.
- Forensic practitioners and agencies can utilize training and technical assistance programs available through federal partnerships, such as those offered by the NIJ Forensic Technology Center of Excellence (FTCoE), BJA's Sexual Assault Kit Initiative (SAKI) and Law Enforcement Cyber Center (LECC), the Federal Law Enforcement Training Centers (FLETC), and many others.
- Forensic agencies and management can implement strategies that support operational readiness, organizational health, and workforce resiliency.

A. Forensic Science Personnel Pipeline

A healthy system not only focuses on the present but also forecasts and plans for the future by crafting the education requirements needed to create qualified and successful personnel, identifying barriers to employment, estimating the numbers of future personnel needed to keep pace with demands for service, and considering continuing education and training needs. [38]

The current forensic science personnel pipeline does not appear to be calibrated to meet future needs, which hinders laboratories and medical examiner and coroner (ME/C) offices from being able to adequately plan for the future. There are several issues responsible for this imbalance, and personnel needs and challenges specifically related to the ME/C system are discussed in the Medical Examiners and Coroners section of this report. First, many students study forensic science but are not interested in pursuing forensic laboratory employment. This means that laboratories are less able to plan based on estimates of forthcoming graduates. This problem is more significant for forensic science than for other fields whose professional programs tend to graduate individuals intending to follow a particular career path. Second, of those who apply to forensic job openings, many cannot pass a basic background check due to past drug use or a minor criminal history. Many students interested in pursuing careers in forensic science are unaware of this prerequisite for employment until relatively late in their education. Third, when qualified candidates are identified and hired, it may take months or years to get them ready for casework. This delay is because forensic analysts are subject to significant training and competency testing to ensure they are capable of getting the correct answer in situations where ground truth is known. Fourth, once hired, qualified examiners are a challenge to maintain because training, whether in-house or outsourced, is expensive and often lengthy. Training is costly to laboratory operations because it consumes the time of senior personnel and can be lengthy if there is a mismatch between the educational experience of the incoming personnel and what the laboratory needs them to know in order to be productive. Fifth, higher salaries in the private sector coupled with burdensome student loan debt, particularly in the areas of forensic pathology and digital analysis, can stifle recruitment and retention efforts and may deter qualified candidates from seeking employment in public service.

Finally, there appears to be a disconnect between the goals of academic programs and the day-to-day needs of forensic science laboratories to meet their mission. While academic programs (accredited and unaccredited) push to produce well-rounded scientists who can think critically and work in a variety of scientific disciplines and environments, laboratories ultimately need scientists who can perform casework and certain technical tasks that are required in a laboratory environment. This means that laboratories are unable to employ recent graduates without additional training. This challenge is not unique to forensic science. Many professional fields (e.g., medicine, law, and social work) require a period of internship or supervised professional training. In addition, academic programs in the forensic sciences lament their limited access to up-to-date and well-maintained instrumentation and equipment on which to educate students. The Technical Assistance Program (TAP) at Marshall University offers an innovative practice to address this limited access issue. TAP, administered by the Marshall University Forensic Science Center, offers pre-trained graduate students with technology-specific training and education to meet a crime laboratory's evaluation and validation needs. For more information on TAP, see the sidebar, "Marshall University's Technical Assistance Program (TAP)."

While most discussion on the personnel pipeline focuses on college students, some listening session participants (LSPs) suggested that it would be appropriate to focus on the pipeline even earlier, specifically in high school. High school students can become interested not only in technician jobs, which may require less education, but also in careers in various aspects of forensic science. The difference between a technician and a forensic scientist could be thought of as analogous to the difference between a medical assistant and a registered nurse. Both are professional careers in a particular field, but one offers a direct path to work for those with limited education.

One area of significant concern is the pipeline for board-certified forensic pathologists, since many career positions in this field lack attractive salaries and present challenges for physicians who must pay back their medical student loan debt. The ME/C community

Marshall University's Technical Assistance Program (TAP)

The Marshall University Forensic Science Center, in cooperation with its forensic science graduate program, offers pre-trained graduate students with technology-specific training and education at a low cost to meet crime laboratories' evaluation and validation needs.

This program, known as the DNA Technical Assistance Program (TAP), is a 12-month program that begins with each student receiving training during the fall and spring semesters (nine months of training in total) in Marshall's state-of-the-art facility. The knowledge and skills acquired include instrumentation, commercial kits, manual and automated laboratory methods, and software programs common to most DNA crime laboratories. When students have satisfied the training and competency requirements to become qualified technical assistants, they become eligible to intern for a maximum of 12 weeks at a DNA crime laboratory, performing customized internal evaluation and validation of DNA technologies based on the client's specifications.

Laboratories participating in TAP not only receive 12 weeks of dedicated assistance and specialized service at a low cost, but also avoid an interruption of their analysts' workflow, since these activities would typically require time away from casework. There is also flexibility in the assignments, so additional assignments can be made during the 12-week period. Additionally, TAP affords the crime laboratory the opportunity to interact with potential job applicants.

For more information on TAP, visit https://www.marshall.edu/forensics/tap.

anticipates that many forensic pathologists will retire within the next decade, and there is a significant shortage of incoming personnel to fill the predicted vacancies. This topic is discussed further in the Medical Examiners and Coroners section of this report.

1. Education

Increasing the availability and quality of forensic science education has long been an area of need. As far back as the 1999 National Institute of Justice (NIJ) publication *Forensic Sciences: Review of Status and Needs,* the forensic community has recognized that their educational and training needs are "immense": [6]

> Training of newcomers to the field, as well as providing continuing education for seasoned professionals, is vital to ensuring that crime laboratories deliver the best possible service to the criminal justice system. Forensic scientists must stay up to date as new technology, equipment, methods, and techniques are developed. While training programs exist in a variety of forms, there is a need to broaden their scope and build on existing resources.

Recommendations from that 1999 NIJ publication were addressed in 2004 by NIJ's Technical Working Group on Education and Training (TWGED). The TWGED report, *Education and Training in Forensic Science: A Guide for Forensic Science Laboratories, Educational Institutions, and Students*, set forth minimum recommendations for designing curricula in forensic science and provided guidance for implementation of these recommendations. [16]

TWGED recognized that government hiring processes are driven by civil service regulations or collective bargaining agreements that are specific to each branch of government, state, and locality. A model candidate for forensic science employment, in TWGED's view, would have: [16]

- Personal integrity
- A minimum of a bachelor's degree in the natural or forensic sciences
- Additional knowledge, skills, and abilities (KSAs) as an aid to employment

Following the publication of the TWGED report, the American Academy of Forensic Sciences (AAFS) created a standing committee in 2004 to convert the TWGED guidelines into enforceable accreditation standards. This committee, the Forensic Science Education Programs Accreditation Commission (FEPAC), provides a mechanism for accrediting forensic science degree programs at the undergraduate and graduate levels, including 47 programs accredited as of 2019. FEPAC's mission is:

> … to maintain and enhance the quality of forensic science education through a formal evaluation and recognition of college-level academic programs. The primary function of the Commission is to develop and to maintain standards and to administer an accreditation program that recognizes and distinguishes high quality undergraduate and graduate forensic science programs. [39]

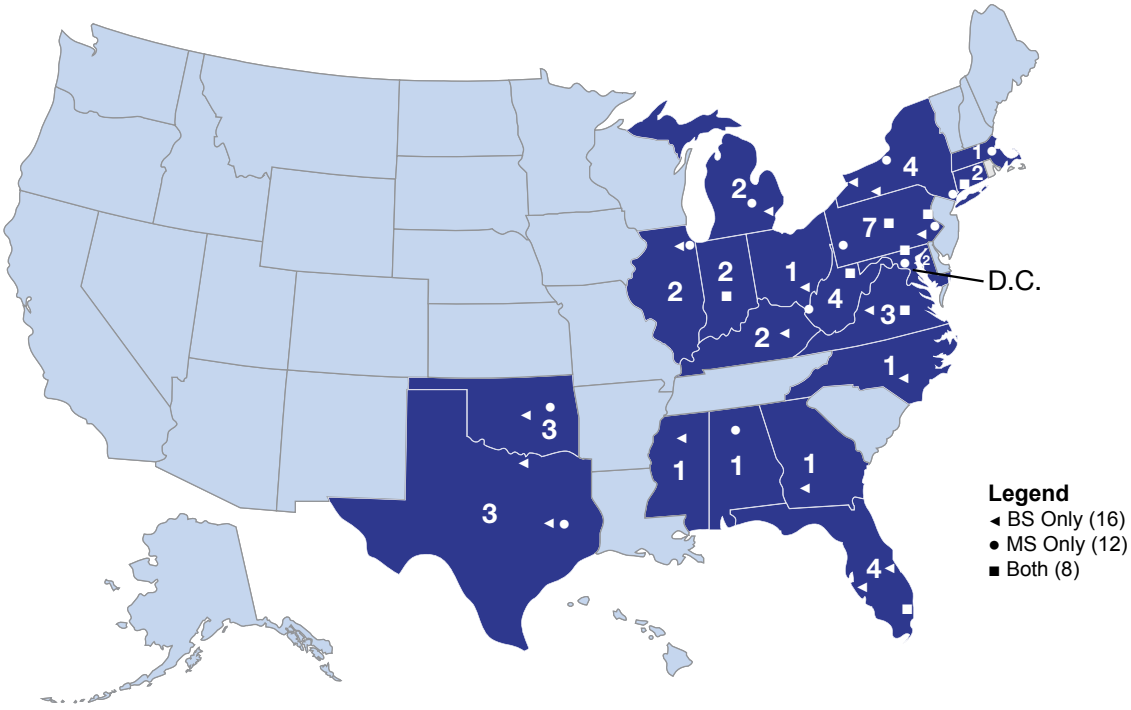
FEPAC standards address the core forensic sciences, biology and chemistry; technical aspects of the profession, such as crime scene processing; and topics related to professional practice including ethics, courtroom testimony, and quality assurance. FEPAC programs

tend to emphasize biology, chemistry, and the physical sciences. FEPAC standards denote which courses and topics are required or desirable, as well as the suitability of facilities, resources, and staffing. FEPAC undergraduate standards include a core curriculum related to the natural sciences. Graduate standards require laboratory practice and research. FEPAC standards for undergraduate and graduate programs in digital evidence have also been created.

The forensic science academic degree programs accredited by FEPAC as of 2019 are located in 20 states (including the District of Columbia), largely east of the Mississippi River (see Figure 1). There are also two FEPAC-accredited programs located in Canada. Of the 47 FEPAC-accredited degree programs located at 36 universities in the United States, 26 programs offer bachelor's degrees and 21 programs offer master's degrees. Eight of the 36 universities offer both bachelor's and master's degrees. [40] The FEPAC-accredited programs located in the U.S. are shown in Table 1, listed alphabetically by state. Programs are required to provide annual reports to FEPAC. FEPAC accreditation is effective for five years and then the program must apply for reaccreditation.

As can be seen from the map in Figure 1, degree programs are concentrated in the Eastern Seaboard and Southern areas of the country, which may impact recruiting and hiring

Figure 1: University Programs Accredited by the Forensic Science Education Programs Accreditation Commission (FEPAC) as of 2019



Note:The numbers represent the number of FEPAC-accredited programs in that state. The shapes indicate the location of the university and type of programs offered (see legend for more information).

Source: Forensic Science Education Programs Accreditation Commission: Accredited Universities [40]

Table 1: U.S. FEPAC-Accredited Forensic Science Academic Programs by State and Degree (as of 2019)

State	University	Degree	Level
AL	University of Alabama Birmingham	Forensic Science	M.S.
CT	University of New Haven	Forensic Science	B.S.
CT	University of New Haven	Forensic Science	M.S.
DC	George Washington University	Forensic Science, Concentration in Forensic Chemistry, Molecular Biology, Forensic Toxicology	M.S.
FL	Florida International University	Certificate in Forensic Science	B.S.
FL	Florida International University	Forensic Science	M.S.
FL	University of Tampa	Forensic Science	B.S.
FL	University of Central Florida	Forensic Science	B.S.
GA	Albany State University	Forensic Science	B.S.
IL	University of Illinois at Chicago	Forensic Science	M.S.
IL	Loyola University at Chicago	Forensic Science	B.S.
IN	Indiana University — Purdue University Indianapolis	Forensic Science and Investigative Sciences	B.S.
IN	Indiana University — Purdue University Indianapolis	Forensic Science and Investigative Sciences	M.S.
KY	Eastern Kentucky University	Forensic Science, Chemistry and Biology Options	B.S.
KY	Eastern Kentucky University	Digital Forensics and Cybersecurity	B.S.
MA	Boston University School of Medicine	Biomedical Forensic Science	M.S.
MD	Towson University	Forensic Chemistry	B.S.
MD	Towson University	Forensic Science	M.S.
MI	Madonna University	Forensic Science	B.S.
MI	Michigan State University	Forensic Biology and Forensic Chemistry Tracks	M.S.
MS	University of Mississippi	Forensic Chemistry	B.S.
NC	Fayetteville State University	Forensic Biology	B.S.
NY	Alfred State College — SUNY	Forensic Science Technology	B.S.
NY	Buffalo State — SUNY	Forensic Chemistry	B.S.
NY	John Jay College of Criminal Justice	Forensic Science	M.S.
NY	Syracuse University	Forensic Science	M.S.
OH	Ohio University	Forensic Chemistry	B.S.
OK	Oklahoma State University	Forensic Science — Forensic Toxicology and Forensic Biology Tracks	M.S.
OK	University of Central Oklahoma	Forensic Science — Chemistry and Molecular Biology	B.S.
OK	University of Central Oklahoma	Forensic Science — Digital Forensics	B.S.
PA	Arcadia University	Forensic Science	M.S.
PA	Cedar Crest College	Forensic Science, Genetic Engineering, Concentration in Forensic Science	B.S.

Table 1. U.S. FEPAC-Accredited Forensic Science Academic Programs by State and Degree (as of 2019) (continued)

State	University	Degree	Level
PA	Cedar Crest College	Forensic Science	M.S.
PA	Duquesne University	Forensic Science	M.S.
PA	The Pennsylvania State University	Forensic Science	B.S.
PA	The Pennsylvania State University	Forensic Science	M.P.S.
PA	West Chester University	Forensic and Toxicological Chemistry	B.S.
TX	University of North Texas	Certificate Programs in Conjunction with Biochemistry, Biology, and Chemistry	B.S.
TX	Sam Houston State University	Forensic Science	M.S.
TX	Texas A&M University	Forensic and Investigative Sciences	B.S.
VA	Liberty University	Forensic Science	B.S.
VA	Virginia Commonwealth University	Forensic Science	B.S.
VA	Virginia Commonwealth University	Forensic Science	M.S.
WV	Marshall University	Forensic Science — Digital Evidence	M.S.
WV	Marshall University	Forensic Science	M.S.
WV	West Virginia University	Forensic & Investigative Sciences	B.S.
WV	West Virginia University	Forensic & Investigative Sciences	M.S.

Source: Forensic Science Education Programs Accreditation Commission: Accredited Universities [40]

for agencies in the Midwest and the Western regions of the nation. In addition to these 47 programs, there are many more academic forensic science programs in operation that are not FEPAC accredited. See Appendix C for a nonexhaustive list of forensic science degree programs, including the FEPAC-accredited programs found in Table 1. Appendix C includes approximately 20 associate degree programs, 60 bachelor's degree programs, and 40 advanced degree programs, in addition to the FEPAC-accredited programs. Many programs list some forensic component, to a greater or lesser degree, depending on the type of degree conferred. Some specialized degree programs are not covered by the FEPAC standards, like forensic anthropology or entomology. Separate academic accreditation schemes may exist for these disciplines outside of the FEPAC process. While TWGED called for forensic science professionals to obtain at least a bachelor's degree, Appendix C also includes associate degree programs. It is important to note the inclusion of these two-year degree options because for many roles in local forensic laboratories, particularly in rural areas, an associate's degree is the minimum qualification for entry-level jobs. An associate's degree in forensic science is designed to prepare students for technical positions in private or public agencies. These programs of study are designed specifically to fill roles in medical examiner offices, police departments, health departments, and other forensic laboratories. The programs focus on teaching skills in crime scene investigation, death investigation, laboratory technology, and/or computer forensics.

Graduate forensic science programs have become important because students without a graduate degree may have limited choices within the forensic science workforce, as some employers prefer applicants with higher-level degrees. It is important to note that the

forensic workforce also hires individuals with undergraduate or graduate degrees from other traditional science programs (e.g., biology, chemistry).

The forensic educational community has expressed a need for doctoral programs to advance research in the forensic sciences and to develop forensic science researchers. Advanced degree programs also prepare forensic scientists, academicians, and researchers for leadership roles in public and private laboratories and academic institutions. [16] Both Sam Houston State University and the West Virginia University recently established doctoral programs in forensic science. These programs were developed in response to the National Research Council's 2009 report, *Strengthening Forensic Science in the United States: A Path Forward* (2009 NAS report) [30], and the national need for terminal degree programs in forensic science to complement the existing FEPAC-accredited master's degree programs. LSPs also noted a severe lack of forensic toxicology graduate programs, exacerbated by the needs associated with the opioid crisis. NIJ's Graduate Research Fellowship Program in Science, Technology, Engineering and Mathematics (GRF-STEM) is one initiative to encourage doctoral research in many forensic science disciplines and to engage the broader scientific community to perform research in forensic science. [41]

The lack of Ph.D. programs also means a small pool of potential faculty. FEPAC standards require that at least 50% of full-time forensic science faculty have an appropriate doctoral degree for each degree program offered. FEPAC noted that, on average, each FEPAC-accredited program has five full-time and two part-time faculty members with doctoral degrees. LSPs noted that academic programs experience challenges with finding qualified candidates when posting a faculty position. An insufficient supply of forensic science faculty candidates is compounded by general constraints in academia, such as decreasing enrollments and pressures related to satisfying core curriculum requirements and caps on program credit requirements. In the forensic sciences, many current faculty were practitioners who transitioned to academia, which is a small pool of potential academics. Filling faculty positions can be challenging due to lower salaries offered in academia, tenure and promotion requirements, and the limited number of positions available in desirable geographic locations.

In order to realign the forensic science education-to-workforce pipeline in a post-TWGED environment, several LSPs suggested increased engagement and discussions between representatives of forensic academic programs and leaders of forensic laboratories (including laboratory directors, human resources personnel, and representatives from the parent agency).

2. Nontraditional Academic Programs

This needs assessment also reviewed nontraditional academic programs, such as forensic anthropology, forensic entomology, and medicolegal death investigation (MDI) programs. According to information provided by FEPAC, the MDI and anthropology disciplines may be considered for the development of new specialized FEPAC accreditation tracks. Another nontraditional discipline that was included in discussions and research for this report is entomology, the study of insects. According to the Entomological Society of America (ESA), there are many programs that offer undergraduate and graduate degrees in entomology, although the ESA does not evaluate these programs. [42, 43] For undergraduate programs, the ESA notes 18 universities offering programs in North America and 25 universities that provide the opportunity to minor in entomology. [42] The ESA graduate-degree program list includes universities in 48 states as well as Puerto Rico, which offer advanced degrees

in entomology or entomology-related disciplines. California has three universities with advanced degrees in entomology or entomology-related disciplines, and Florida, New York, Texas, and Utah each have two. The other states represented on the ESA graduate degree program list only have one program offered per state. There are also nine universities in Canada offering graduate entomology programs. [43] Table 2 provides a list of undergraduate and graduate entomology programs in the United States. This list is developed from the ESA undergraduate and graduate program lists and may not be all-encompassing. These programs are also included in Table 10, located in Appendix C, which

Table 2: U.S. Entomology Programs by State and Degree (as of 2019)

State	University	Degree	Level
AL	Auburn University	Entomology	M.S., Ph.D.
AZ	University of Arizona	Entomology and Insect Science	M.S., Ph.D. Minor
AR	University of Arkansas	Entomology	M.S., Ph.D.
CA	University of California—Davis	Entomology	B.S., M.S., Ph.D.
CA	University of California—Riverside	Entomology	B.A./B.S., M.S., Ph.D.
CO	Colorado State University	Entomology	M.S., Ph.D.
DE	University of Delaware	Insect Ecology and Conservation	B.S.
DE	University of Delaware	Entomology	M.S.
DE	University of Delaware	Entomology and Wildlife Ecology	Ph.D.
FL	Florida A&M University	Agricultural Science with Concentration in Entomology	M.S.
FL	Florida A&M University	Entomology—Cooperative program with University of Florida	Ph.D.
FL	University of Florida	Entomology and Nematology	B.S., M.S., Ph.D.
GA	University of Georgia	Entomology	B.S., M.S., Ph.D.
HI	University of Hawaii at Manoa	Entomology	M.S., Ph.D.
ID	University of Idaho	Entomology	B.S., M.S., Ph.D.
IN	Purdue University	Insect Biology, Forensic Sciences Minor Offered	B.S.
IN	Purdue University	Entomology	M.S., Ph.D.
IA	Iowa State University	Insect Science	B.S.
IA	Iowa State University	Entomology	M.S., Ph.D.
KS	Kansas State University	Entomology	Graduate Certificate, M.S., Ph.D.
KS	University of Kansas	Entomology	M.A., Ph.D.
KY	University of Kentucky	Entomology	B.S., M.S., Ph.D.
LA	Louisiana State University	Entomology	M.S., Ph.D.
MD	University of Maryland	Entomology	M.S., Ph.D.
MI	Michigan State University	Entomology	B.S., M.S., Ph.D.
MN	University of Minnesota	Entomology	M.S., Ph.D.

Table 2: U.S. Entomology Programs by State and Degree (as of 2019) (continued)

State	University	Degree	Level
MS	Mississippi State University	Agricultural Life Science with Concentration in Entomology	M.S.
MS	Mississippi State University	Life Sciences with a Concentration in Entomology	Ph.D.
MO	University of Missouri	Entomology	M.S., Ph.D.
MT	Montana State University	Entomology	M.S.
NE	University of Nebraska—Lincoln	Insect Science—Science Option	B.S.
NE	University of Nebraska—Lincoln	Entomology	M.S., Ph.D.
NJ	Rutgers University	Entomology	B.S., M.S., Ph.D.
NM	New Mexico State University	Agricultural Biology with Concentration in Entomology	B.S.
NY	Cornell University	Entomology	B.S., M.S., Ph.D.
NY	State University of New York—Syracuse	Environmental and Forest Biology	M.S., M.P.S., Ph.D.
NC	North Carolina State University	Entomology	M.S., Ph.D.
ND	North Dakota State University	Entomology	M.S., Ph.D.
OH	The Ohio State University	Entomology	M.S., M.P.S., Ph.D.
OK	Oklahoma State University	Entomology, with Bio-Forensics Option	B.S.
OK	Oklahoma State University	Entomology	M.S., Ph.D.
OR	Oregon State University	Crop Science, with Concentration in Entomology	M.S., Ph.D.
OR	Oregon State University	Horticulture, with Concentration in Entomology	M.S., Ph.D.
PA	The Pennsylvania State University	Entomology	M.S., Ph.D.
SC	Clemson University	Entomology	M.S., Ph.D.
TN	University of Tennessee	Entomology and Plant Pathology	M.S.
TN	University of Tennessee	Entomology, Plant Pathology, and Nematology	Ph.D.
TX	Texas A&M University	Entomology	B.S., M.S., Ph.D.
VA	Virginia Tech University	Entomology	M.S., Ph.D.
WA	Washington State University	Entomology	M.S., Ph.D.
WV	West Virginia University	Plant and Soil Sciences with Concentration in Entomology	M.S.
WI	University of Wisconsin—Madison	Entomology	M.S., M.P.S., Ph.D.
WY	University of Wyoming	Entomology	M.S., Ph.D.

Source: ESA Universities, Courses and Entomology Clubs Page [42-43]

provides a list of forensic science academic degree programs in the United States. Most individuals who elect to work as forensic entomologists complete an entomology degree, then specialize in forensic science or minor in forensic entomology. [44]

To work as a forensic anthropologist, a higher-level degree, preferably a doctorate, is required in most instances. [19, 45] Becoming a "diplomate" of the American Board of Forensic Anthropology (ABFA) is the highest recognition in the field, with the vast majority of diplomates holding a doctoral degree. [46] While the ABFA does not accredit programs, it does provide a list of 38 universities that have at least one ABFA diplomate on their faculties, with these universities appearing in Table 3. Many of these programs are also included in Table 10, located in Appendix C. [47] There are two primary career paths for a forensic anthropologist: academia or ME/C offices. A small number of forensic anthropologists also work at the Defense POW/MIA Accounting Agency or in public health. Most forensic anthropologists work in academia, teaching and conducting research, while consulting on cases as needed. Anthropology students receive broad training so that they are versatile in research and are able to interact with other disciplines (e.g., archeology and the ME/C community).

Table 3: U.S. Universities With at Least One ABFA Diplomate on Faculty by State (as of 2019)

State	University	State	University
AZ	Arizona State University, School of Human Evolution and Social Change	MO	St. Louis University—School of Medicine
AZ	University of Arizona	NV	University of Nevada, Reno
CA	California State University, Chico	NY	Binghamton University
CA	California State University, Los Angeles	NC	North Carolina State University
CA	University of California—Santa Cruz	NC	Western Carolina University
CO	Colorado State University	OH	Mount St. Joseph University
CO	Metropolitan State University of Denver	OH	The Ohio State University
DC	The George Washington University	PA	Mercyhurst College
FL	Florida Gulf Coast University	TN	Middle Tennessee State University
FL	University of South Florida	TN	University of Tennessee, Graduate School of Medicine and Department of Anthropology
HI	University of Hawaii at Manoa, John A. Burns School of Medicine, and the Department of Anthropology	TX	Sam Houston State University, College of Criminal Justice
IN	University of Indianapolis	TX	Texas A&M University
IA	Des Moines University	TX	Texas State University—San Marcos
KS	Washburn University	VA	George Mason University
LA	Louisiana State University	VA	Radford University
MA	Boston University School of Medicine	VA	Virginia Commonwealth University
MI	Michigan State University	VA	Virginia Tech University, Carilion School of Medicine
MN	Hamline University	WI	University of Wisconsin—Madison

Source: ABFA Active Diplomates Page [47]

While there are many academic programs available that offer degrees in general forensic science or that focus on a specific laboratory discipline, there are only a few degree programs available for MDI or forensic medicine (primarily at the graduate level). [48-52] There are even fewer standardized education and training requirements for autopsy assistant positions, according to LSPs. There is also a critical shortage of forensic pathologists, which may be due to the lack of competitive salaries, given that government salaries for forensic pathologists are less than industry averages for pathologists. LSPs noted that there needs to be more exposure to forensic pathology in medical school and that medical examiners and coroners need to advocate for incentives associated with choosing this line of work. Additionally, it is recommended that students training to be forensic pathologists be exposed to a wide variety of forensic disciplines to provide a well-rounded education, as well as the ability to communicate and work with a variety of stakeholders in death investigations.

Some jurisdictions, such as Maricopa County, Arizona, have offered student loan repayment incentives to attract forensic pathologists (see the sidebar, "Maricopa County Medical Examiner Loan Repayment Assistance Program (MELRAP)," for more information), while other ME/C offices have attracted candidates to the pipeline by offering a rotation program for medical students (see the Medical Examiners and Coroners section of this report for further information and promising practices). Through this rotation, students are trained on how to interface with the ME/C system, and some students choose to enter the forensic pathologist pipeline as a result of these rotations. Another way to access these students is through education and outreach programs, such as those programs provided through the District of Columbia Office of the Chief Medical Examiner, which have been instituted to build a pipeline for various MDI positions (see the sidebar, "District of Columbia Office of the Chief Medical Examiner (DC OCME)").

3. Internships/Experience

The forensic educational community has disagreed with the notion that the only desirable outcome for a forensic science graduate is a position within a forensic laboratory. Academic programs of all kinds tend to believe it is the mission of higher education to produce well-rounded graduates capable of critical thinking. This creates a dual concern for forensic academic programs: They must produce students who are prepared to work in a forensic laboratory while also being adaptable to other scientific and commercial career paths. Since many, if not most, institutions cap the credit hours at 120 for undergraduate degrees and at 30 to 60 hours for master's level graduate degrees, it can be challenging for both programs to meet both goals.

This difficulty is not unique to forensic science. Other scientific academic programs are recognizing that a traditional, linear career path is not feasible for every graduate in a discipline. Training and exploration programs, especially in the life sciences, have been developed to identify approaches for broadening career development in fields with limited positions available. [53]

While internships provide opportunities to gain real-world experience, they are not without challenges for both students and laboratories. Students may be challenged by a limited number of nearby laboratories willing to take interns, the requirement to work without pay, and limited time for internships due to other curricular requirements. Laboratories have difficulty integrating unskilled workers for a short period of time into a highly controlled

laboratory environment. Nevertheless, it is widely agreed that internships are a net positive. Laboratories have developed some practices to ensure the experience is meaningful for both the student and the laboratory. LSPs noted that some students participate in the National Science Foundation's Research Experience for Undergraduates (NSF REU) program, which supports research development and prepares students for graduate-level research. [54] The NSF REU program provides travel and work stipends for undergraduate students to conduct directed summer research. The forensic science community could collaborate with academic research institutions that operate NSF REU program sites to develop research projects with forensic science applications. Additionally, some faculty noted the importance of training students about the needs of the laboratories. Other LSPs noted cooperative agreements between local laboratories and universities. These types of agreements may help to enhance the employment pipeline: Interns learn agency policies and procedures, making them better prepared for employment with that particular agency. As examples of collaborations between laboratories and universities that can advance the employment pipeline, communities have developed internship programs such as the District of Columbia Office of the Chief Medical Examiner (DC OCME), which attracts and prepares students for the MDI workforce, and Marshall University's TAP (see the sidebars).

District of Columbia Office of the Chief Medical Examiner (DC OCME)

The District of Columbia Office of the Chief Medical Examiner (DC OCME) has academic affiliations with local universities. Through these academic affiliations, DC OCME offers an internship program, allowing students to participate in an internship rotation at the OCME to gain a better understanding of patient anatomy, physiology, forensic investigation, and mortuary sciences. OCME has a vested interest in developing a skilled workforce through the educational advancement of students studying, or having a demonstrated interest in, one or more of the critical functions of the OCME, including forensic toxicology, mortuary sciences, forensic pathology, medicolegal death investigation, government administration, and legal services. Given that OCME recognizes the need for clinical experiences in the training of current and future forensic science students, the OCME makes certain personnel, staff, and facilities available to provide a clinical educational experience for student interns.

For further information, see: https://ocme.dc.gov/page/educational-information.

B. Workforce Landscape

According to the 2014 Bureau of Justice Statistics (BJS) Census of Publicly Funded Forensic Crime Laboratories, laboratories employed 14,300 full-time employees (FTEs), which included 12,200 FTEs employed by state, county, or municipal laboratories. [5, 34] Previous BJS Crime Laboratory Censuses identified the total number of laboratory FTEs for all jurisdiction levels to be 11,000 in 2002, 12,200 in 2005, and 13,100 in 2009. At the state and local levels in 2014, this is an increase of 1,400 FTEs since 2009, an increase of 2,400 FTEs since 2005, and an increase of 3,100 FTEs since 2002. [3, 4] Furthermore, an analysis of Project FORESIGHT data through 2017 estimates a current nationwide deficit of over 900 FTEs for county, city, and state laboratories. [37] The workforce landscape of the ME/C system is discussed in further detail in the Medical Examiners and Coroners section of this report.

The U.S. Bureau of Labor Statistics (BLS) reported in its Occupational Outlook Handbook that the size of the occupation of forensic science technicians included 15,400 jobs with a median salary of $57,850 per year for 2017. BLS also reported for its Job Outlook and Job Prospects information that: "Employment of forensic science technicians is projected to

grow 17% from 2016 to 2026, much faster than the average for all occupations. However, because it is a small occupation, the fast growth will result in only about 2,600 new jobs over the 10-year period. State and local governments are expected to hire additional forensic science technicians to process their high caseloads. Additionally, scientific and technological advances are expected to increase the availability, reliability, and usefulness of objective forensic information used as evidence in trials. As a result, forensic science technicians will be able to provide even greater value than before, and more forensic science technicians will be needed to provide timely forensics information to law enforcement agencies and courts. Competition for jobs is expected to be strong. Applicants who have a master's degree should have the best opportunities." [55]

In order to identify information about forensic services provided outside of the crime laboratory environment, a 2008 study examined results from a Forensic Awareness Survey of local city police and county sheriff departments.[2] [21] The study found that:

- Average employment of departments was 120, with 4.3% of employees working directly on forensics.
- Sixty percent of departments reported having one or more employees who work directly on forensic services.
- Eighty-five percent of departments reported that they conduct crime scene investigations; all other services fall below the 60% threshold (e.g., photography, footwear, latent print, digital evidence).
- Departments with forensic services have an average of 8.6 employees who work directly on forensic services.

C. Hiring

One of the biggest challenges of hiring new personnel is background checks. Many new applicants to forensic science are unable to pass standard background checks due to minor criminal history or drug use. These difficulties have been compounded by recent state-level changes in legislation regarding the use of marijuana. Those seeking careers in this field should be aware that background checks similar to those required for law enforcement officers are likely to be a condition of employment. Background investigations may be conducted and/or reviewed before an employment offer is made and may recur as an ongoing condition of employment. [16] FEPAC accreditation standards require that students "shall be advised and informed of the typical suitability requirements particular to employment in the field." [56]

Background investigation requirements, including polygraph examinations, dramatically reduce applicant pools for both interns and new hire candidates. One agency reported that utilizing a pre-screen interview often reduces the pool of interview-successful candidates by approximately 40%. [57] Rather than suggesting that background investigations are not appropriate, LSPs believed that earlier socialization and education would be

[2] The survey was mailed to 15,918 U.S. police chiefs and sheriffs. Surveys were completed by 1,219 departments. The survey collected data from 899 forensic scientists in public and private laboratories operating at the local, state, and federal levels across the United States.

helpful. They suggested that forensic science students should receive the same type of information that criminal justice majors seeking law enforcement employment receive — discussions of appropriate behavior, use of social media, and the potential consequences of their decisions. Some universities have chosen to have students complete background investigations or similar processes either as a condition for program admission or as a requirement for graduation in an effort to increase the employability of students and reduce the screening burden on employers. For example, Marshall University requires a successful background check as a condition of admission to the graduate program in forensic science. While Marshall has not yet had a student fail the background check, Marshall program representatives noted that some alumni have responded positively to these background checks, stating that they serve as a good barometer for a student's ability to seek employment after graduation. Additionally, Cedar Crest College has developed a guide for admissions counselors to provide to all prospective students interested in forensic science (see the sidebar, "Cedar Crest College — Qualifications for a Career in Forensic Science").

Cedar Crest College — Qualifications for a Career in Forensic Science

Forensic science is a part of the criminal justice system. Therefore, those seeking careers in forensic science should not only hold a bachelor's degree in natural sciences, but must also possess personal integrity, scientific objectivity, and honesty. Furthermore, potential applicants should be aware that background checks are likely to be a condition of employment.

Background checks have been cited by the forensic community as a hurdle to getting qualified forensic practitioners hired. To address this issue, Cedar Crest College has developed a guide for admissions counselors to provide to all prospective students interested in forensic science. This guide informs interested students of the expectations of forensic science professionals in both their personal and their professional lives. Additionally, it provides a list of conditions of employment, to include drug tests, history of drug use, criminal history, driving record, and personal associations. It also provides guidance on the academic qualifications and professional skills essential for a successful career in forensic science.

The goal of Cedar Crest's guide is to make potential candidates aware of these expectations and conditions early, so they can make the right choices as they prepare for their career and prevent these conditions of employment from becoming barriers in their career path. The guide is based on the 2004 NIJ special report, Education and Training in Forensic Science: A Guide for Forensic Science Laboratories, Educational Institutions, and Students. [16]

Furthermore, on-boarding and training new employees to the point of competency (i.e., when they are approved to process casework) can be expensive and time-consuming, with some specialties requiring years of training. This situation is compounded by the desire of some students to pursue whatever forensic laboratory job they can find, as opposed to a position in which they have particular interest or aptitude. This may be another gap between the education and employment sectors in relation to the pipeline: Determining an individual's aptitude early in their education and encouraging them to take a strengths-based approach to learning and specialization is a mechanism for developing a pipeline of the best candidates for limited positions. Some students are deciding to pay their own way through training programs to achieve competency and obtain professional certifications, sometimes in lieu of paying for graduate degree programs, in order to become more attractive candidates when vying for job openings.

Professional forensic scientists and academicians repeatedly expressed the need to create opportunities where all parties could discuss their concerns, needs, and resources for

the betterment of the forensic enterprise. This echoes the overarching need found in this assessment for facilitating and supporting a systems-based approach. The topics of discussion should include:

- Academic curriculum
- Determination of aptitude or suitability for discipline and/or specialization
- Requirements for training to competency
- Practical skill sets in the laboratory and critical thinking skills
- Educational requirements for institutions
- Reduction of costs and time associated with training to competency
- Internships
- Programs for advising students prior to choosing a forensic major, especially regarding career requirements
- Significant training opportunities relevant to laboratory needs

These topics could also be addressed by considering the professional roles, desirable qualifications and training, and academic resources available for sworn personnel and civilians. Sworn forensic personnel are certified law enforcement officers who have additional training to work in a forensic capacity, whereas civilian forensic positions are typically hired from a pool of candidates with forensic science and/or physical science backgrounds. LSPs noted that in the laboratory, sworn officers often occupy apprenticeship-style positions for disciplines such as firearms examination.

D. Training

Virtually all new employees — whether they are experienced analysts or recent graduates, and whether they have forensic science degrees or traditional physical science degrees — will require significant training to become eligible for performing casework. This is because each laboratory has its own set of equipment, policies, and standard operating procedures. An experienced analyst may require less training, while an employee who has limited or no operational laboratory experience will require more time to become eligible for performing casework. This is particularly the case in disciplines like firearms and other pattern disciplines which utilize an apprenticeship style of training. These apprenticeships may last years, discouraging mid-career professionals from becoming cross-trained in those disciplines. In response to these challenges, some students are being encouraged to self-sponsor through training programs. Training needs for the ME/C system will be discussed in the Medical Examiners and Coroners section.

Training needs for forensic laboratories are significant, driven by the increased demand for trained staff and succession planning. In *Forensic Sciences: Review of Status and Needs*, published in 1999, training was identified as one of the four major areas of need within the forensic science community. [6] The assessment of training needs for the forensic community provided in that report is still valid today. In 2004 the American Society of

Crime Laboratory Directors (ASCLD) reported that for an analyst in a one-year training program, the cost of just the salary paid to the individual in training is estimated at $30,000 to $40,000 per year. The actual cost to train a person for one year is likely greater, estimated to be in excess of $100,000, and there are also subsequent intrinsic costs because the trainer's attention will be diverted from performing casework and because there are additional costs associated with laboratory training supplies. These costs can be magnified for laboratories that experience high turnover rates.

The cost of continuing professional development varies, depending on the requirements of the specialty. [58] The FBI's Quality Assurance Standards for Forensic DNA Testing Laboratories states that a minimum of eight cumulative hours of continuing education are required annually and shall be documented for the technical leader, casework Combined DNA Index System (CODIS) administrator, and analyst(s). [59] TWGED recommended that between 1% and 3% of the total forensic science laboratory budget be allocated for training and continuing professional development. [16] BJS reported in its 2002 Crime Laboratory Census that the training budgets of the largest 50 laboratories in the United States were less than 0.5% of their total annual operating budgets. Laboratories may also want to consider the costs to achieve and maintain certifications for their forensic personnel.

The 2004 NIJ report of the status and needs of forensic science service providers indicated a need for increased availability of training opportunities and noted that regional centers could expand the scope and delivery of training programs. Regional or technology-based academies could be established, using the FBI Academy as a model. [60] Free or low-cost online training opportunities can also offer numerous benefits, allowing personnel to receive continuing education and professional development, reducing training costs associated with travel and per diem, while also limiting the amount of time that personnel will be diverted from casework. One training option available for state and local personnel is the Federal Law Enforcement Training Center (FLETC) in Glynco, Georgia. Further, the FLETC campus in Artesia, New Mexico, provides investigative and forensic training to state, local, and tribal communities. These state-of-the-art FLETC facilities offer unique and cutting edge training opportunities on a variety of forensic topics and disciplines (see the sidebar, "Federal Law Enforcement Training Centers (FLETC)").

The length of the initial training provided to an analyst depends upon the laboratory specialty area that the trainee will enter. [16] For example, controlled substance analysts may require only six to 12 months of training. Individuals who are training in disciplines such as latent print examination, firearms and toolmark analysis, and questioned documents examination may require up to three years of training or longer before demonstrating competency to perform independent casework. During their training period, individuals in experience-based disciplines serve much like an apprentice to a senior examiner. LSPs identified an overarching need for minimum training standards for each discipline. Most LSPs suggested that developing national training standards and training programs can help mitigate training challenges, with potential support from federal and university partners.

Similarly, as noted by ASCLD, some crime laboratories have attempted to collaborate on initial training, sending their trainees to a single site. The Illinois State Police has accepted individuals from other states/laboratories into their training programs when space exists, and regional computer forensic laboratories administered by the FBI can be a way to

Federal Law Enforcement Training Centers (FLETC)

As part of their mission, the Federal Law Enforcement Training Centers (FLETC) deliver research-informed, evidence-based training to federal, state, local, and tribal personnel. All FLETC advanced training is open to state, local, and tribal law enforcement officers, although training sessions may be limited by available seats and funding. For state and local officers, 95% of FLETC training is tuition free. FLETC provides meals and lodging, so agencies only need to pay for travel expenses. Training can include civilian personnel as long as they are employed by a sponsoring agency.

The training is available at FLETC facilities or can be conducted at regional locations nationwide by FLETC instructors. Additionally, FLETC's campus in Artesia, New Mexico, offers a variety of investigative programs, such as crime scene investigation (CSI) and death investigations training, for new tribal law enforcement. Often, trainings for tribal communities include multiple agencies, such as the FBI, Bureau of Indian Affairs, and tribal police personnel. FLETC maintains a public website for state and local officers to request training (https://www.fletc.gov/state-local-tribal-law-enforcement-training) and also employs six full-time FLETC state, local, and tribal regional coordinators to liaise with law enforcement to support their training needs. Medical examiners and coroners are also eligible to participate in FLETC training programs.

The Forensics and Special Investigative Skills (FSI) branch of FLETC instructs in all three of FLETC's flagship basic training programs and delivers specialized training in multiple advanced programs. FLETC's Crime Scene Investigators Training Program (CSITP), for example, is a seven-week advanced forensics technical program where students receive specialized training in the application of forensic science to CSIs. Students learn and demonstrate proficiency in crime scene management and processing; crime scene and evidence documentation; advanced latent print, impression, trace, and biological evidence development; shooting scene reconstruction; bloodstain pattern recognition and documentation; fire scene investigation; post-blast crime scene processing; recovery of subsurface remains and entomology collection; and expert witness testimony.

FSI's training programs are delivered almost exclusively within the Forensic Science Training Complex, a 40,000 square foot facility designed specifically to prepare students to apply the most current and relevant forensic processes and techniques in investigations. The facility is composed of 11 specialized classrooms, three forensic laboratories, a four-bay garage, 14 crime scene modules, 19 staff offices, and a digital photography laboratory. All students in the digital photography courses leave with the camera and equipment used in training, which are built into the course cost, so that they can immediately implement their training in the field.

State, local, and tribal officers can learn more about training opportunities at https://www.fletc.gov/state-local-tribal-law-enforcement-training. Applications for student training can be found at https://sass.fletc.dhs.gov/fast.

maximize training in digital evidence across stakeholders (see the sidebar, "Regional Computer Forensic Laboratory — Training in Digital Evidence"). This collaboration not only expands training opportunities but also inspires consistent messaging and training across the community, making cross-agency collaboration and troubleshooting efforts more practicable.

Federal laboratories also collaborate with state and local forensic service providers in many other ways. They provide resources for research, training, and technology transfer. Federal laboratories also maintain and support investigative databases for firearms, fingerprints, and DNA. The FBI has provided on-site and online training for local and state agencies via its Virtual Academy, though the forensic community would like to see the federal forensic science training programs expanded to meet current and future needs. One specific recommendation for expanded training is to strengthen the support given to crime laboratories and other crime scene/disaster scene first responders with respect to terrorism or other events that might result in mass casualties, including support for training,

equipment, and coordination activities. Recognizing the need for experienced personnel in firearms, the Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) National Firearms Examiners Academy (NFEA) is expanding to meet the needs of the field. (See the sidebar, "The Bureau of Alcohol, Tobacco, Firearms and Explosives' National Firearms Examiners Academy (NFEA).")

Initial training of laboratory analysts is performed largely on the job and is labor intensive. Training is also required on a continuing basis to maintain and update knowledge and skills. Some professional associations provide recommendations for the content of training programs and may provide training and continuing education opportunities to support professional certifications. Collaborations, innovative approaches, and alternative delivery systems for forensic analyst and manager training are needed. Regional centers based on established programs would be suited for expanded training. [58] Training does not stop once a new employee has reached proficiency and can begin casework. To maintain proficiency, and in some cases to maintain both individual certifications and facility accreditations, forensic personnel must frequently undergo continuing education and professional development. There are many sources for continuing education and professional development, such as the Forensic Technology Center of Excellence (FTCoE), Sexual Assault Kit Initiative (SAKI), or Law Enforcement Cyber Center (LECC).

Yet it is important to mention that resources are needed to properly support training and continuing professional development. (See the sidebars, "Sexual Assault Kit Initiative Training and Technical Assistance (SAKI TTA)" and "Bureau of Justice Assistance Law Enforcement Cyber Center (LECC).") In addition to their regular duties, qualified forensic

The Bureau of Alcohol, Tobacco, Firearms and Explosives' National Firearms Examiners Academy (NFEA)

The National Firearms Examiners Academy (NFEA) of the Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF), implemented in 1999, is currently the only national training program to provide a standardized training curriculum for education in the forensic firearm field. The NFEA was developed through a collaboration between the ATF Office of Science and Technology's National Laboratory Center and the Association of Firearm and Toolmark Examiners. NFEA provides training to apprentice (i.e., entry-level) firearm and toolmark examiners from federal, state, and local law enforcement agencies. The one-year training curriculum covers the fundamentals of firearms and toolmark examinations and provides trainees with the tools and education to become a qualified firearm and toolmark examiner. Applicants are required to meet a number of criteria for selection into the program. NFEA staff evaluate the applicant's home laboratory needs and their ratio of trainees to qualified examiners. When possible, NFEA gives preference to applicants from states that have not had a previous attendee. ATF is in the process of expanding NFEA to offer a larger class size.

There are four phases of the training, covering 18 distinct modules provided over the course of one year:

- Phase I – Pre-course assignments, reading, and research (four months)
- Phase II – Instruction and practical exercises at ATF's Forensic Science Laboratory (17 weeks)
- Phase III – Individual research projects at the student's own agency laboratory (four months)
- Phase IV – Preparation for the presentation of expert testimony in Washington, D.C. (two weeks)

For more information, visit: https://www.atf.gov/resource-center/docs/nfea-course-overview/download.

Additionally, NFEA also offers two courses in Serial Number Restoration (three-day training) and Toolmark Identification and Comparison (five-day training) to address the need for training in specific forensic areas. For more information on ATF's Firearms-Related Training for Law Enforcement, including application instructions, visit: https://www.atf.gov/resource-center/docs/nfea-course-overview/download.

Sexual Assault Kit Initiative Training and Technical Assistance (SAKI TTA)

The National Sexual Assault Kit Initiative (SAKI) Training and Technical Assistance (TTA) program, administered by the Bureau of Justice Assistance (BJA), provides resources and expertise to jurisdictions as they prepare best practices for collecting and processing forensic evidence, investigating and prosecuting sexual assault cases resulting from evidence in previously unsubmitted sexual assault kits, and supporting sexual assault survivors. This program addresses sexual assaults from a criminal justice perspective, which encourages a coordinated community effort to resolve sexual assault cases. Resources offered through this program include:

- Webinars covering a range of topics, including investigations, forensic testing, prosecution strategies, victim notification, the neurobiology of trauma, offender research, and more. See https://sakitta.org/webinars.
- A virtual academy with e-learning curricula that provides guidance on issues related to unsubmitted sexual assault kits. See https://academy.sakitta.org/course.
- The Sexual Assault Kit Initiative Toolkit, with resources and tools for practitioners working to improve their community's response to sexual assault. See https://sakitta.org/toolkit.
- Tailored on-site or remote technical assistance and training for any jurisdiction in need.

scientists and supervisors are expected to receive time to continue professional development and to mentor trainees. Agency management is expected to plan for any effects that reallocating laboratory resources may have on case productivity. A partnering model can also be extended to continuing professional development, with agencies working together to develop and provide a standardized training curriculum and materials for use across several agencies. Although these partnerships can significantly reduce costs, funding for student attendance may still be needed. [16]

LSPs suggested the need for collaborative training that united academic and practical needs, where a university setting is used to host or provide field-relevant and applied training that is supported by research and evidence. One model of a university-practitioner partnership, which was sponsored by federal grant programs,[3] is the Law Enforcement Innovation Center National Forensic Academy housed at the University of Tennessee, which focuses on training for crime scene investigators. This training program demonstrated how federal resources can be leveraged to create partnerships that are then maintained and supported by the community, and this particular program helps prepare participants for taking International Association for Identification (IAI) certification tests. The same model may be applied to other areas and disciplines, and is described further in the sidebar, "The University of Tennessee Law Enforcement Innovation Center's National Forensic Academy."

LSPs noted that it is not just laboratory professionals who need access to quality, standardized training; law enforcement, legal professionals, judges, and laboratory managers and supervisors also need access to similar forensic training. The lack of forensic education among legal professionals has contributed to a misunderstanding of standard laboratory disciplines. Similarly, laboratory professionals could benefit from a better understanding of the legal system to improve communication and coordination. In addition, laboratory supervisors and managers may lack supervision skills, knowledge

[3] NIJ award numbers 2002-LP-CX-K006, 2009-DN-BX-K190, and 2011-DN-BX-K567; BJA award number 2011-DP-BX-K049.

The University of Tennessee Law Enforcement Innovation Center's National Forensic Academy

Crime scene investigators, particularly in the wake of the 2009 NAS report, have realized the need for standardized training that emphasizes current practices and research in crime scene processing. The University of Tennessee Law Enforcement Innovation Center's National Forensic Academy trains individuals in advanced crime scene investigations. Students learn to process crime scenes correctly and consistently using standardized practices provided by experts in their fields. This also includes specialized training in excavation of human remains and various factors impacting human decomposition provided by the University of Tennessee Forensic Anthropology Center, which is also conducting research supported by NIJ.[1]

The practical skills and applied knowledge taught during the 10-week program are cumulative, and the scenarios allow the participants to practice using their skills repeatedly. Graduates of the National Forensic Academy are equipped to enter the field with the tools and skills necessary to send collected evidence to laboratories for specialized analysis, leading to successful prosecutions or innocence protected.

For more information, visit: http://leic.tennessee.edu/home/training/forensic-training/national-forensic-academy/.

[1] NIJ award numbers 2018-DU-BX-0180, 2017-R2-CX-0008, and 2016-DN-BX-0179.

of fiscal procedures, and project management expertise, which could improve laboratory efficiency. [58] In response to this need, the ASCLD Leadership Academy was established in 2014 and is designed to help laboratory supervisors develop leadership skills. The academy implements a blended training model, combining weekly lecture-style webinars with hands-on, practical exercises. Additionally, NIJ's Forensic Technology Center of Excellence (FTCoE), in partnership with ASCLD, developed the online FTCoE Leadership Series, with the goal of introducing leadership concepts, such as process and analytical reliability, workforce competency, efficiency, implementation of technologies and best practices, and overall quality in the laboratory.

Training should be available to criminal justice system stakeholders so they understand forensic analysis decisions and strategies. Two examples of this type of training can be found at the Arizona Forensic Science Academy and the National Clearinghouse for Science, Technology and the Law (NCSTL). The Arizona Forensic Science Academy is particularly promising, as it is a state-level program that embodies the systems-based approach so prevalent in this report. (See the sidebars, "The Arizona Forensic Science Academy — Collaborative Training" and "National Clearinghouse for Science, Technology and the Law (NCSTL).")

Continued advancement of forensic science personnel requires that appropriate resources for training and development be provided by the parent agency. As the field moves more towards standardization and certifications, which mandate continuing training and professional development, this will be an ongoing issue that must be addressed.

The Arizona Forensic Science Academy — Collaborative Training

The Arizona Forensic Science Academy (FSA) is a model program overseen by a multidisciplinary board that creates training programs specifically designed for criminal justice practitioners, including attorneys (prosecutors, defense attorneys, and judges), forensic scientists, and other members of the criminal justice community. The FSA was developed in response to the recommendation in the 2009 National Research Council publication, *Strengthening Forensic Science in the United States: A Path Forward* to provide forensic science training to legal professionals. The Arizona Forensic Science Advisory Committee of the Attorney General's Office created the FSA to teach forensic principles and scientific methodologies, as well as to identify evidentiary concerns. The uniquely collaborative board is made up of prosecutors and defense attorneys, as well as representatives from the courts, the medical examiner, the crime laboratory, and the Arizona Criminal Justice Commission. Together the board members identify the topics and instructors for each academy curriculum, using local and national experts as faculty.

The FSA offers both basic and advanced programs, as well as specialized programs on specific topics or for a targeted audience. The basic and advanced academy classes are both held one afternoon a week, for six to eight weeks. Admission to the program is by application and includes a registration fee which ranges from $30 to $300. The program includes a forensic textbook, which participants have found useful for future trial preparation.

Basic academy topics include:

- Crime scene investigation
- Toxicology
- Controlled substances
- Forensic biology/DNA
- Firearms
- Latent prints
- Digital evidence
- Death investigation

The advanced academy provides an in-depth analysis of forensic science disciplines and also includes an ethics component. The FSA's specialized training programs include the "3-D Academy," which focuses on forensic issues related to domestic violence, drugs, and driving while intoxicated. In addition to the longer programs, the FSA offers a lecture series of stand-alone, four-hour lectures and has developed webinars for participants who cannot travel to the lecture locations.

The FSA has partnered with the Arizona Judicial College and the Arizona Supreme Court to develop training courses for judges at all levels. It also provides continuing education for forensic scientists. Since its inception in 2011, the FSA has provided over 1,400 criminal justice professionals with 14,000 hours of continuing education.

Traditionally, training of this type is exclusive to either prosecutors or defense attorneys, and prosecutors and defense attorneys rarely attend the same training event. The FSA programs are different. Regardless of which specific FSA program an attorney attends, legal advocacy is left at the door. When prosecutors and defense attorneys attend an FSA training, the sole focus is on increasing individual competency regarding the forensic sciences. After attending the program, both prosecutors and defense attorneys have demonstrated an improved understanding of core principles and scientific methodologies when examining forensic scientists at trial.

The FSA has received national recognition for its programs. Its curriculum is ever-evolving based on both scientific and legal developments. It has improved relationships among the various stakeholders, increased their understanding of forensic science principles, and provided access to the resources available in Arizona crime laboratories. This is a model program that other jurisdictions have sought to replicate.

For more information, see the Arizona Attorney General's website at https://www.azag.gov/criminal/azfsac or contact Jody Wolf, chair of the FSA and the Crime Laboratory Administrator of the Phoenix Police Department Laboratory Services Bureau, at Jody.Wolf@phoenix.gov and FSA board member Elizabeth Ortiz, executive director of the Arizona Prosecuting Attorneys' Advisory Council, at Elizabeth.Ortiz@apaac.az.go.

National Clearinghouse for Science, Technology and the Law (NCSTL)

Judges, lawyers, scientists, and law enforcement officers have a responsibility to promote justice based on sound science. However, educating themselves in the vast array of science and technology information available to meet legal challenges can be overwhelming. The National Clearinghouse for Science, Technology and the Law (NCSTL), funded by a grant from the Bureau of Justice Assistance (BJA) through its Capital Litigation Initiative, offers a series of live seminars and webinars about forensic science and scientific evidence. These training events are intended for potential capital litigators, both prosecution and defense, who want to learn more about forensic science as it relates to capital cases. Registration is free, and travel costs (for live seminars) are covered by BJA. Additionally, attendees who complete the trainings are eligible for free continuing legal education credits. Webinars and seminars from the 2016-2017 Crime Scene to Courtroom Forensics Series are available at: http://www.ncstl.org/education/Crime%20Scene%20to%20Courtroom%20Forensics%20Webinars. As more trainings become available, information will be posted on the NCSTL website at http://www.ncstl.org/education/TRAINING.

E. Certifications

The forensic sciences have moved steadily towards advancing national standards in the past decade in response to the 2009 NAS report. [29, 30] Several organizations now provide professional certifications for personnel, including certifications for medicolegal death investigation by the American Board of Medicolegal Death Investigators (ABMDI), for crime scene investigation by the International Association for Identification (IAI), for anthropology by the American Board of Forensic Anthropology (ABFA) through board certification, for various digital and multimedia evidence examinations, and many more. In 2014, the National Science Technology Council, Committee on Science, Subcommittee on Forensic Science compiled a list of forensic certification programs developed for several disciplines. The list was updated in 2016 by the National Commission on Forensic Science. (See Appendix A in the Views of the Commission on Certification of Forensic Science Practitioners [61]). As positions requiring these certifications become more common, there will be funding needs associated with gaining and maintaining certification, including costs of examinations, costs and time for continuing education and professional development, and consideration for higher salaries for certified personnel. [32]

According to the 2014 BJS Crime Laboratory Census: [5, 62]

- The proportion of crime laboratories employing one or more analysts with external certification increased from 60% in 2009 to 72% in 2014.
- In 2014, about 9 in 10 crime laboratories with 50 or more full-time personnel employed at least one externally certified analyst. In comparison, about 45% of laboratories with nine or fewer full-time employees employed one or more externally certified analysts in 2014.
- Crime laboratories with professional accreditation (74%) were more likely than crime laboratories without accreditation (57%) to employ at least one externally certified analyst.

Overall, LSPs identified the primary barriers to certification to be a lack of funding and the inability to remove staff from casework during the time required to become certified. For example, to become an IAI-certified latent print examiner, one needs a minimum of 80 hours of approved latent print training. Some agencies cannot afford to send their examiners to 80 hours of training, and in smaller agencies training is done in-house. To increase the number of certified personnel, LSPs suggested that training needs to be viewed as an asset, not a hurdle, and more emphasis needs to be placed on why certifications are important.

As the field continues to develop and focus on standardization and professionalization, certifications may be required by more agencies for certain positions, meaning that the challenges described in the training and education sections above will likely be amplified.

F. Health and Wellness

It is now commonly acknowledged that traditional first responders — police, firefighters, emergency medical services, dispatchers, and correctional officers — experience stress and various forms of trauma, including vicarious trauma, over the course of their careers. Efforts to address and mitigate stress-related impacts are becoming more widespread. There is legislation intended to provide critical services to treat PTSD resulting from these job-related traumas, however it explicitly excludes civilian personnel, which leaves a large portion of the forensic workforce without access to these services.

Forensic personnel are just beginning to be acknowledged as similarly experiencing trauma. The forensic science workforce routinely operates in a high stress occupational environment, and disciplines such as crime scene unit personnel, forensic nurses, MDI professionals, laboratory analysts, and digital examiners also have significant exposure to trauma. [63-68] Forensic science practitioners and death investigators respond to violent crime and death scenes, including homicides, sexual assaults, child and infant fatalities, and line-of-duty deaths. The workforce faces large workloads, persistent backlogs, and pressure to provide results in a timely manner while maintaining quality standards. Crime scene response personnel conduct on-site scene processing and evidence collection, including screening of biological fluids, bloodstain pattern analysis, and forensic photography, often with limited time and resources and in a physically demanding environment. Scene operations require sufficient coordination with additional law enforcement personnel to maintain scene security and personnel safety to focus on the tasks at hand. Digital evidence examiners process various types of image, video, audio, and other multimedia evidence, including graphic evidence from violent crimes and child exploitation cases. Medical examiners, coroners, and medicolegal death investigators routinely investigate sudden and unexpected deaths and suspicious or violent deaths, and they communicate directly with grieving families and next of kin while gathering additional information to aid the death investigations. [69, 70] ME/C personnel conduct forensic autopsies and interview subjects regarding the circumstances of death. Even analysts working primarily in the laboratory environment are not immune from occupational stressors as they handle the physical evidence from violent crimes. Fear for personal safety has increased with the opioid epidemic, because even trace amounts of fentanyl and related analogues present hazardous situations for both field and laboratory personnel. The effects of these stressors can impact forensic personnel in both their personal and professional lives unless appropriate assistance is provided to bolster resilience and coping.

Work stressors can impact personnel health and wellness and result in lost productivity and reduced services. Moreover, all forensic personnel can experience these potential sources of stress repeatedly throughout their careers, which can result in cumulative stress, vicarious trauma, and even compassion fatigue or Emergency Responder Exhaustion Syndrome (ERES). [71] Vicarious trauma is a common occupational challenge for staff within the criminal justice system and can result from direct or indirect exposure to traumatic events. The Office for Victims of Crime (OVC) has recognized this challenge, and in response developed the Vicarious Trauma Toolkit (VTT), which includes tools and

Office for Victims of Crime Vicarious Trauma Toolkit (VTT)

It takes courage to help child and adult victims of sexual abuse, assist survivors of terrorism and mass violence, fight fires that may have taken people's lives, or respond to shootings and other crime scenes. It also takes commitment to do this work despite the personal, physical, emotional, and mental impact it can have. The Vicarious Trauma Toolkit (VTT) [72] was developed on the premise that exposure to the traumatic experiences of other people — known as vicarious trauma — is an inevitable occupational challenge for the fields of victim services, emergency medical services, fire services, law enforcement, and other allied professions. However, organizations can mitigate the potentially negative effects of trauma exposure by becoming vicarious trauma-informed.

The VTT includes tools and resources that provide the knowledge and skills necessary for organizations to address the vicarious trauma needs of their staff. To begin exploring the VTT, select from the discipline-specific resources and the comprehensive Compendium of Resources located at https://vtt.ovc.ojp.gov. While the VTT content was tailored for the aforementioned professional fields, the VTT can be applied to a broader range of disciplines, including forensic laboratories and ME/C offices. The Vicarious Trauma — Organizational Readiness Guide (VT-ORG) is a starting point for organizations that want to become vicarious trauma-informed and proactively address the impact of vicarious trauma. It can be used to assess an agency's current capacity as a vicarious trauma-informed organization, identify strengths and gaps, and prioritize needs. For more information, visit https://vtt.ovc.ojp.gov/the-vt-org-and-other-tools.

The National Institute of Justice Forensic Technology Center of Excellence also recently developed a webinar series in response to the need to address vicarious trauma for forensic professionals. The series introduces the VTT, explores common strategies and resources derived from existing research, and offers guidance to forensic practitioners and the broader criminal justice community on how they can be leveraged. Additionally, participants learn recommended methods to maintain workforce resiliency.

resources that provide the knowledge and skills necessary for organizations to address the vicarious trauma needs of their staff. [72] While this toolkit is tailored towards victim services, emergency medical services, fire services, and law enforcement, it can be applied to a broader range of disciplines, including forensic laboratories and ME/C offices (see the sidebar, "Office for Victims of Crime Vicarious Trauma Toolkit (VTT)"). Digital forensics, in particular, has taken steps to address these needs in the workforce. For example, the Supporting Heroes in Mental Health Foundational Training (SHIFT), developed by the Internet Crimes Against Children (ICAC) program, a program of DOJ's Office of Juvenile Justice and Delinquency Prevention (OJJDP), provides a model that can be adapted to other forensic disciplines. [73] (See the sidebar, "Supporting Heroes in Mental Health Foundational Training (SHIFT) Wellness Program.")

While occupational stress, vicarious trauma, and compassion fatigue have been explored in law enforcement and medicine, few studies examine the impact on forensic science personnel. [65-67, 70, 74-79] Tools developed for similar fields may be tailored to mitigate the stressors experienced by the forensic science workforce. [64, 66, 70, 72, 74, 76, 80-85] Several recent proceedings of forensic science professional organization meetings demonstrated the impact of these job responsibilities on personnel stress, burnout, and vicarious trauma, and the need for greater awareness and strategies to mitigate their impact, particularly for different types of forensic science positions. [67, 85-90] Some LSPs discussed strategies they have implemented to combat these issues, including access to psychological support through employee assistance programs, peer support from outside agencies, utilizing chaplain services, having psychologists come in after critical incidents, and working with organizational psychologists to address organizational issues that arise from psychological roots.

Supporting Heroes in Mental Health Foundational Training (SHIFT) Wellness Program

The Innocent Justice Foundation has partnered with the Department of Justice's Office of Juvenile Justice and Delinquency Prevention (OJJDP), Internet Crimes Against Children (ICAC) task force commanders, and leading global mental health experts in the child sexual abuse field to develop a program that helps professionals exposed to child sexual abuse materials recognize and cope with the negative effects of viewing child abuse images. The Supporting Heroes in Mental Health Foundational Training (SHIFT) wellness program provides one of the first comprehensive and foundational training programs in the United States to address this problem. Learn more at http://www.shiftwellness.net/. [73]

Resources available through the SHIFT program include:

- SHIFT Upper-Level Management (Administrator's) Guide
- SHIFT Unit Commander Guide
- SHIFT Friends and Family of Exposed Individuals Guide
- SHIFT Confidentiality Guidelines

Through the use of SHIFT tools and resources, recommendations from the Innocent Justice Foundation, and collaboration with other ICAC task forces around the country, the ICAC Task Force of the Cuyahoga County, Ohio, Prosecutor's Office has implemented a wellness policy designed to give investigators the tools to cope with the stress and vicarious trauma of their positions. Cuyahoga County's new policy mandates annual group and one-on-one assessments with a mental health professional (MHP) and encourages investigators to engage in self-care activities, such as attending wellness programs and trainings, creating a safety plan, and meeting with the ICAC MHP as needed (outside of the annual mandate). Additionally, the task force established a wellness committee to identify and implement wellness opportunities and activities to increase the mental well-being of task force personnel and affiliates.

Experts in organizational and occupational psychiatry and law advise that professionals who operate in stressful work environments respond to different types of triggers, and they also require individualized response and recovery approaches. Forensic science personnel and their management should foster communication to gain a better awareness and understanding of the risk factors and conditions affecting the forensic service providers in their occupational environment.

The forensic science community has voiced a need to understand how to provide and promote resources that mitigate and manage occupational stressors. ASCLD recently established a task group to help laboratory managers better understand these issues. [66] Furthermore, the NIJ FTCoE responded to this need by initiating the "Forensic Workforce Resiliency: Vicarious Trauma and Workplace Stress Webinar Series" in September 2018. [91] Through a partnership with OVC, the first webinar leveraged the Vicarious Trauma Toolkit to identify common strategies and resources derived from existing research and offer guidance to forensic practitioners. This first webinar clearly demonstrated both need and interest in the field, with over 360 individuals participating in the live webinar. These efforts need to be directed beyond current personnel; academic forensic programs need to include health, wellness, and vicarious trauma in their curricula to adequately prepare students for the workforce. Law enforcement also recognizes the importance of providing support not only to their sworn employees, but also to their civilian employees. It was recommended in the 2019 Report to Congress on the Law Enforcement Mental Health and Wellness Act that civilian employees, particularly dispatch, forensic, and crime scene investigation staff, be afforded the same mental health and wellness services as their sworn colleagues, asserting that civilians engage in the same incidents that cause stress for officers, just in a different capacity. [92] These efforts will support operational readiness, organizational health, and workforce resiliency, and prepare prospective forensic scientists for future careers in these professions.

IV. Workload

Needs:

- The ability to process and analyze increasing amounts of forensic evidence.
- The ability to increase laboratory capacities and system efficiencies to meet forensic testing demands and address evidence backlogs.
- The ability to process, analyze, and interpret forensic data in a timely manner to contribute to investigative leads.
- Increased criminal justice system stakeholder collaboration and communication with the laboratories to better understand and calibrate expectations, track status as cases are processed through the system, and inform evidence submissions, testing priorities, and laboratory decision-making.
- Upstream utilization of forensic science to generate actionable information for developing investigative leads and downstream to meet court dates.

Challenges:

- Insufficient resources, capacity, infrastructure (including laboratory facilities and limitations of available space), personnel, and information technology.
- Increased complexity of forensic analysis and testing requirements for some evidence types (e.g., digital and multimedia evidence, toxicology, and DNA mixtures).
- Stakeholder systems (e.g., law enforcement, laboratory, and prosecutor) that lack the capability to share case information between systems.
- Hiring and retaining qualified staff.
- Lack of dedicated funding for all forensic disciplines beyond DNA analysis.
- Implementation of new workflow processes or emerging technologies may contribute to short term workload challenges or delays.

Promising Practices:

- Systems-based approaches to making informed decisions regarding forensic evidence submissions and requests for analysis.
- Implementation of Lean Six Sigma methodologies to reduce waste, better utilize resources, and work more efficiently (reducing turnaround times and backlogs).
- Innovative mechanisms to better utilize current resources and facilities to increase efficiencies (e.g., lean facility design).

A. Workload Landscape

As forensic testing becomes more sensitive and critical to resolving crimes, there is an increase in the utilization of forensic science services. Furthermore, more evidence from property crimes is being sent to laboratories for forensic testing, and cold case and post-conviction testing is becoming more common. The growing demand for forensic services has far outpaced the resources allocated. [24] Forensic science service providers, as noted in the various listening sessions, are feeling the pressures of this increased demand in their workload, and they are experiencing challenges in responding to those demands in a timely manner in order to better serve justice and provide investigative leads. There are many ways to measure and track workload over time — requests received, tests performed, cases that are backlogged, and length of time to process a case (i.e., turnaround time). A discussion specifically related to workloads is provided in the Medical Examiners and Coroners section of this report.

Federal funding programs such as the National Institute of Justice's (NIJ) DNA Capacity Enhancement and Backlog Reduction program (DNA CEBR) and Paul Coverdell Forensic Science Improvement Grants program (Coverdell program) are heavily utilized by states and units of local government, and these programs are often cited as critical and necessary to forensic laboratory, medical examiner/coroner (ME/C) offices, and other forensic science service provider operations. The Bureau of Justice Statistics (BJS) Census of Publicly Funded Forensic Crime Laboratories reported that, in 2014, 77% of publicly funded crime laboratories received funding from grants (this includes federal, state, or other grant sources), an 8% increase from 2009. [63, 93] Federal funding levels that support backlog reduction and capacity enhancement of DNA analysis at state and local forensic laboratories have remained steady over the last several years, but similar dedicated funding is not available for all other forensic disciplines. While Coverdell program funding may be used to address evidence backlogs in any forensic discipline (including DNA analysis) and to help improve the quality and timeliness of any forensic science and medical examiner/coroner service through several permissible grant purposes, the annual Coverdell program funding is consistently lower than the available annual funds dedicated specifically for DNA testing. For instance, Coverdell program funding was $10.6 million in FY 2017, while dedicated DNA testing funds awarded in that year totaled $67.7 million (see the sidebar, "The Paul Coverdell Forensic Science Improvement Grants Program" for more information on the grant purposes available through the Coverdell program). States regularly expend all available formula-based funding appropriated under the Coverdell program, yet state and local laboratories still consistently express that the total funding levels are insufficient to meet their needs, including the need to process extensive backlogs of non-DNA evidence. [94, 95] The Coverdell program receives almost 100 applications annually for the

competitive portion of the funding. However, only 10%-30% of these projects are typically funded, due in part to the limited funding allocated to the Coverdell program. [96] While recent legislative changes have increased the authorized funding levels incrementally for FY 2017 to FY 2021[4] and the FY 2018 and FY 2019 appropriations provided additional Coverdell program funding to target the challenges the opioid epidemic has brought to the forensics community, the legislative changes also reduced the portion of Coverdell program funding available for competitive awards, from 25% to 15% starting in FY 2017 (see Sec. 9 of the Justice for All Reauthorization Act of 2016 for more information). [1]

Nevertheless, these federal grant programs are intended to supplement and support state and local funding and have not eliminated the considerable need for additional resources and capacity. State and local entities must assess their priorities in forensic science and choose how to proceed based on those priorities. While the federal funding programs provide significant support, state and local government budgets provide much more direct funding, with state, county, and municipal laboratory operating budgets estimated to total $1.379 billion in 2014. [34] It is important to recognize that states are beginning to conduct their own needs assessments, as state and local leaders may be best situated to identify site- and system-specific needs, in addition to troubleshooting and developing strategic solutions to address their greatest needs. For example, the National Forensic Science Technology Center at Florida International University (NFSTC@FIU) conducted a needs assessment for the Wisconsin State Crime Laboratory Bureau. [36] The report indicated that both case submissions and turnaround times were increasing. In addition to assessing the needs of the laboratory, NFSTC@FIU provided recommendations to improve productivity and efficiency. Wisconsin's attorney general used the findings and recommendations from the needs assessment to support specific actions and budgetary requests to increase the laboratory's capacity and workload. The attorney general also called upon the governor and legislature to fund the core elements of the criminal justice system that lie outside of the Wisconsin Department of Justice's budget, namely prosecutors, public defenders, and the court system. [35]

An analysis of the Project FORESIGHT data for this needs assessment demonstrated that the estimated funding gap for the 2017 level of forensic casework was $640 million.[5] [37, 38] The gap was largest in areas associated with the opioid crisis and untested sexual assault kits. The funding gaps for capital and labor suggest that substantial investment in forensic crime laboratories is needed to merely maintain the current level of requests. Furthermore, the growth in the total laboratory budget for the typical laboratory has been under 3% per year for the past decade. However, for two particular areas of investigation — drugs/controlled substances and toxicology — the growth in expenditures from FY 2015-2016 to FY 2016-2017 was dramatic. The median laboratory growth rate in expenditures was 37% for drugs/controlled substances and 26% for toxicology, far outpacing the growth in total laboratory expenditures. As a result, there is a substitution effect as resources are diverted from elsewhere in the laboratory to address casework in these areas. [37, 38] This diversion of resources can also affect a laboratory's decisions to accommodate personnel training and continuing education, and laboratories must balance competing priorities when faced with any new influx of cases.

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[4] Authorized funding levels for the Coverdell program were $13,500,000 for FY 2017, $18,500,000 for FY 2018, and $19,000,000 for FY 2019. They are $21,000,000 for FY 2020 and $23,000,000 for FY 2021.

[5] All discussions of Project FORESIGHT rely on an assumption that FORESIGHT is representative of all publicly funded laboratories

The BJS Crime Laboratory Censuses conducted in 2002, 2009, and 2014 collected data on crime laboratory services, budgets, staffing, workload, outsourcing, and quality assurance practices.[6] [63, 93, 97] The 2014 BJS Census reported that the nation's 409 crime laboratories received an estimated 3.8 million requests for forensic services and completed 3.6 million requests that year. [97] The majority of these requests were for analysis of controlled substances (33% of requests), biological samples from convicted offenders and arrestees (24% of requests), and toxicology (15% of requests). This does not vary much from the proportions of requests received in 2009. The BJS Census also yielded information regarding the current status of crime laboratory backlogs, outsourcing efforts, and personnel. At the end of 2014, U.S. crime laboratories had an estimated backlog of 570,100 requests for forensic services.[7] The largest contribution to backlog was due to controlled substances requests, representing 37% of the overall backlog for all U.S. forensic laboratories in 2014; the number of backlogged controlled substances requests rose from 139,200 in 2009 to 213,700 backlogged requests in 2014. [63] While backlogged requests for latent print and toxicology services constituted a smaller portion of the overall laboratory backlog in 2014 (12% and 7%, respectively), backlogged latent print requests increased from 49,500 in 2009 to 69,400 in 2014 and backlogged toxicology requests increased from 27,600 in 2009 to 40,000 in 2014. [67] Forensic biology casework samples accounted for 19% of the overall backlog at the end of 2014, a slight increase from 103,500 backlogged requests in 2009 to 107,800 requests in 2014. As noted in the report "NIJ Fiscal Year 2017 Funding for DNA Analysis, Capacity Enhancement, and Other Forensic Activities," while DNA CEBR funding efforts to reduce backlogs of biological evidence have resulted in significant improvements in the quantity and quality of DNA testing, a reduction in the backlog has been tempered by a substantial increase in the demand for testing. The increased demand is due in part to improvements in DNA evidence analysis through technology advancements (see Figure 2: Trends in DNA Testing of Forensic Cases). [98]

The 2014 BJS Census reported on the requests for services received and completed for the various forensic disciplines, and it appears that laboratories are making strides to complete requests for forensic services as changes in workloads occur, especially in the testing of biological samples (see Table 4 in the BJS report "Publicly Funded Forensic Crime Laboratories: Resources and Services, 2014" [63]). However, since 2014 there have been many advances in the science and technology used in laboratory operations. As new technologies and high-throughput systems are implemented, laboratories can process samples more quickly, particularly through automation. These workflow processes could partially account for the significant decrease in backlogs in DNA database casework (e.g., convicted offender and arrestee samples), which decreased by 85% from 2009 to 2014.[8] [34] In addition, NIJ's DNA CEBR program found that demand for database casework

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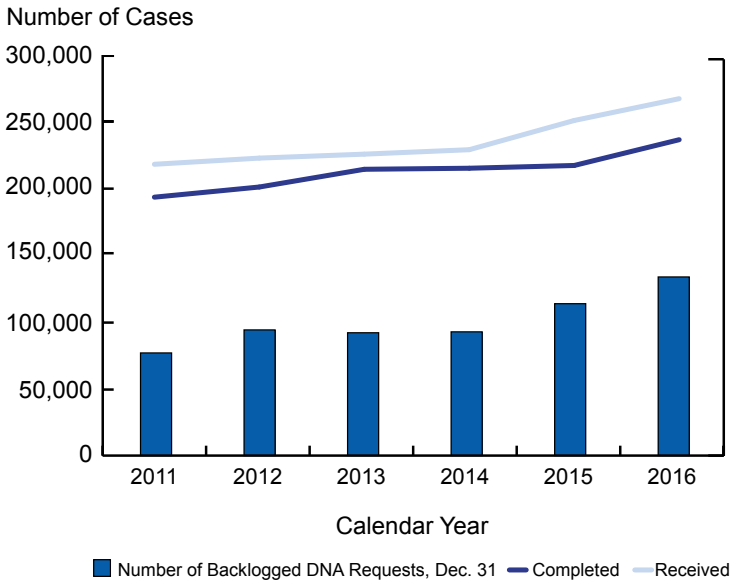
[6] The data collection was directed at federal, state, county, and municipal crime labs funded solely by the government or whose parent organization is a government agency. The 2014 BJS Census [61] included agencies that employ one or more full-time scientists with a minimum of a bachelor's degree in chemistry, physics, biology, criminalistics, or a closely related forensic science field, and whose principal function is examining physical evidence in criminal matters and providing reports and testimony to courts of law regarding such evidence.

[7] A backlogged request is defined in the BJS Census as a request that has been submitted to a specialized area of the crime laboratory and it was not examined and reported to the submitting agency within 30 days of submission.

[8] It is important to note that the BJS Census reported: "Biological samples collected from convicted offenders or arrestees for a DNA database that were backlogged decreased from 502,500 at yearend 2009 to 64,800 at yearend 2014. The FBI crime lab reported the majority of these backlogged requests in 2009 because of an increase in the collection of DNA samples as mandated by federal legislation. Since 2009, the FBI crime lab has reduced its backlog of requests for DNA samples taken from convicted offenders and arrestees. The overall reduction in DNA samples led to a decline in the overall number of backlogged requests within U.S. crime labs observed at yearend 2009." [34]

Figure 2: Trends in DNA Testing of Forensic Cases [98]



decreased between 2011 and 2016, and a significant percentage of requests were closed administratively for reasons such as sample submissions from nonqualifying offenses or duplicate submissions. [99]

Laboratory upgrades, such as high-throughput systems and automation, are streamlining activities and increasing capacity to process more forensic evidence, while also enabling screening to occur in the field, yielding more thoughtful requests for laboratory analysis. Advances in technology are also providing more sensitive instrumentation, with improved limits of detection. While these advancements can provide even more data with probative and evidentiary value, laboratories must develop strategies to address corresponding challenges for data interpretation. Additionally, the use of laboratory information management systems (LIMS) has become more critical and widely embraced by laboratories for case tracking and providing accurate and quantitative data to properly assess the needs, successes, and limitations of laboratories. Between 2002 and 2009 there was an almost 10% increase in the use of LIMS to manage tasks and pieces of evidence received from criminal investigations. In 2014 approximately 9 out of 10 publicly funded laboratories had a LIMS. LIMS can be utilized at various levels, from simply tracking evidence, to connecting to laboratory instrumentation for automated data dumps, to sharing case status information. [3] Table 2 demonstrates what functions are being performed by LIMS within the crime laboratories surveyed in the BJS Census, showing an increase in utilization since 2009 for most functions. [63] The increased use of LIMS is enabling BJS and Project FORESIGHT to retrieve more accurate quantitative data for statistical analysis and economic assessments.

The BJS Census data from 2014 revealed fewer requests for forensic services between 2009 and 2014. [34] However, because a forensic request can involve multiple items and multiple tests per item, the number of requests can be misleading. [100] Project FORESIGHT defines backlogs as the number of open cases at the end of the fiscal year that have been open for more than 30 days. FORESIGHT data revealed that the average backlog — which grew nearly 250% between 2011 and 2017 for almost all 18 areas of investigation tracked by FORESIGHT — is growing faster than the growth in case submissions. [37, 38]

Table 2: Functions Performed by LIMS in Surveyed Crime Laboratories [3, 63]

LIMS Function	Percentage of Laboratories With LIMS Function	
	2009	2014
Tracking by:		
Item	89%	94%
Request	90%	93%
Law Enforcement Case Number	95%	97%
Laboratory Case Number	97%	98%
Calculating Turnaround Time	84%	84%
Tracking Criminal Case Status	31%	31%
Interfacing With Laboratory Instrumentation	24%	27%
Monitoring Backlog	88%	88%
Chain of Custody	90%	94%
Generating Reports	92%	94%

This trend is also observable in the BJS Census data. For example, requests for toxicology services remained high, showing a slight decrease based on estimated totals from 2009 to 2014, but the backlog in toxicology appears to be increasing. In the area of drugs/controlled substances, there was also a slight decrease in requests for services, but an increase in backlog. So while the analysis of convicted offender/arrestee DNA samples (accounting for about 1 in 4 of the service requests received in 2009) has become more efficient, showing a significant reduction in backlog from 2009 to 2014, this trend is not shared by all disciplines.

Turnaround time is often used to assess the efficiency and performance of a laboratory. This metric has been a point of discussion among stakeholders, and it is often misunderstood and misinterpreted. Turnaround time is generally defined as the number of days between the submission of a request for forensic analysis to the laboratory and the delivery of the test results or issuance of a report. If analysis has not been completed within 30 days of an item's receipt by the laboratory, that item is generally considered backlogged.[9] [101] These definitions can vary within the community, creating miscommunications and misunderstandings between stakeholders, the general public, and Congress. Some listening session participants (LSPs) expressed the need for universal definitions and noted that the expected turnaround time should be realistic and discipline specific, depending on the complexity of the analysis. For some evidence types, such as toxicology, digital evidence, and DNA mixtures, the analysis may be complex, leading to longer turnaround times. An analysis of the Project FORESIGHT data for this needs assessment demonstrated that turnaround times grew dramatically in nearly every area of investigation between 2011 and 2017, and that the size of the average 30-day backlog grew along with it. [37, 38] On average, each area of investigation has seen a 60% increase in turnaround time; some areas have had even more dramatic increases. In particular, the turnaround time for gunshot

[9] The BJS Census defines a backlogged request as a request that has been submitted to a specialized area of the crime laboratory and not examined and reported to the submitting agency within 30 days of submission. For data collection purposes, Project FORESIGHT defines backlogs as the number of open cases at the end of the fiscal year that have been open for more than 30 days.

Casework Terms

DNA casework can be tracked according to the number of *cases*, *items*, and *samples* submitted for testing and analysis. In the definitions used by Project FORESIGHT, *casework* is all laboratory activities involved in the examination of cases; an *item* is a single object for examination submitted to the laboratory; and a *sample* is an item of evidence or a portion of an item of evidence that generates a reportable result.

To understand the difference between these three terms, consider the following examples:

- A stabbing (*case*) may involve a knife (*item*) that is submitted for laboratory analysis, where blood on both the hilt and blade (*samples*) are swabbed for DNA testing.
- Sexual assault kit evidence submitted from a sexual assault (*case*) typically includes several swabs and other evidence types (*items*) associated with the assault that can be sampled by the laboratory (*samples*) for examination using a variety of DNA testing techniques.

residue analysis has more than doubled, and the rise in demand for digital analysis has caused a near tripling of the turnaround time. Again, it is believed that turnaround time is increasing in part due to advances in technology and the complex nature of newer analyses.

Furthermore, FORESIGHT data collected over the past decade permit a review of the changes in the demand for DNA casework over time, to include changes in the number of cases, items, and samples submitted for testing and analysis (see the sidebar, "Casework Terms"). [37, 38] Measuring the changes via the queuing elasticity of demand[10] shows that a 1% reduction in turnaround time for DNA casework leads to a 1.29% increase in cases submitted to the laboratory for analysis the following year. That is, the backlog is not going away in the near future; rather, the backlog is increasing as laboratory analysis becomes more successful. What laboratories gain in efficiencies is more than offset by increases in casework. Further, that same 1% reduction in turnaround time results, on average, in a 3.9% increase in the number of items submitted per case. As more cases and items are submitted to the laboratories for analysis, the laboratories also demonstrate a 2.9% increase in samples analyzed. Part of the increased production can be explained by the increased productivity that accompanies greater economies of scale. Any efforts to reduce turnaround times will require greater capabilities in terms of laboratory space, equipment, and consumables, as well as additional personnel, to handle the influx of associated casework demands.

Backlogs are not necessarily an indicator of a laboratory's performance and may even be the direct result of the increasing demand for forensic services. A laboratory can be efficient and effective but, due to limited capacity, continue to have an increasing backlog. [34] For example, NIJ reported that between 2011 and 2016, forensic DNA requests increased by 21.9%, while the cases completed increased by 21.6%. [98] Laboratories are increasing their capacity, just not at the same rate as the demand is increasing. LSPs noted that in response to this ever-increasing demand, some laboratories limit the number of samples or items that can be submitted or no longer offer certain forensic services in order to meet the demand in other disciplines.

Furthermore, the concept of "artificial backlogs" needs to be considered. Artificial backlogs describe evidence awaiting analysis in a laboratory despite being no longer needed for

[10] The queuing elasticity of demand is calculated by dividing the percentage change in casework requests by the percentage change in turnaround time.

investigating, trying, or adjudicating the case in question. One report cited three main reasons for artificial backlogs:

1) Evidence is submitted without the intention to use or rely on a laboratory analysis.

2) Evidence is in the queue for analysis, but the case has been settled, dismissed, or disposed of, making analysis no longer necessary.

3) Evidence is collected, as a result of the "CSI effect," to demonstrate that the victim has received the full resources of the agency, and the evidence is processed and stored, but the evidence is never actually analyzed (i.e., symbolic evidence collection). [103]

LSPs identified the second reason above as a perpetual problem, often the result of limited communication or ineffective case tracking systems between laboratories, prosecutors, and law enforcement. LSPs reported that many cases are disposed of without prompt notification to the laboratories, and they suggested that this occurs with a quarter of the cases in general and up to three-quarters of drug cases. A 2011 study of controlled substance processing in 10 jurisdictions found that 50% to 75% of the drug case backlog consisted of cases that had already been pled out or dismissed. [104] The failure of stakeholders to communicate case status can result in unnecessary analysis and use of resources, inaccurate backlog statistics, and ultimately delays in serving justice. This issue goes beyond the laboratory and requires all stakeholders involved in a case to implement a systems-based approach to addressing forensic cases. Artificial backlogs could be addressed through critical thinking, strategic planning, and evidence triage.

In addition to the provision of casework, laboratory personnel are expected to provide court testimony when requested. This can often be a time-consuming process, and it necessarily requires the examiner to be away from the laboratory. LSPs from a larger state laboratory noted that their laboratory collected statistics on the time it took to commute to the courthouse, wait to provide testimony, and testify; one LSP noted that their office found that the personnel time expended for testimony over the course of one year equated to employment of five full-time employees (FTEs). Compounding this issue, LSPs explained, they are often not notified of a court cancellation until they are at the courthouse. Once again, this limited communication and lack of a systems-based approach among all stakeholders creates an unnecessary burden on forensic personnel. A 2016 RAND report on "Fostering Innovation in the U.S. Court System" identified a high-priority technology need to allow specialists to appear via video presence to increase the efficiency of staff usage. [104] This report specifically noted that by addressing this need, laboratories will have an opportunity to address backlogs in forensic laboratories and delays in evidence processing. LSPs strongly supported this recommendation to alleviate workload demands and reduce time away from the laboratory. However, courts and laboratories may not have the infrastructure to support the technology requirements associated with video testimony.

B. Systems-Based Approaches to Addressing Workload Challenges

A systems-based approach — where law enforcement, laboratory personnel, medical examiners/coroners, and prosecutors collaborate on cases, are properly educated and trained in the science, and work together to serve justice in a timely and efficient

manner — is the best way to address workload issues. This approach requires increased communication and coordination regarding notification of case status and improvements in electronic information sharing. LSPs indicated a need for notification regarding case status, including notification of when analysis and testimony is no longer required. Courts can also benefit from sharing timely and accurate laboratory information with their internal case management and electronic records management systems, and system compatibility can facilitate these processes and aid in case preparation. [104] Many jurisdictions have formed task forces (see the sidebar, "The New York City Police Department Laboratory's Customer Working Group (NYPD CWG)") or state commissions to develop the necessary relationships and trust between law enforcement, laboratories, and the legal community. These types of partnerships can also foster regular communication and collaboration on cases, allowing jurisdictions to successfully take a systems-based approach to address the workload needs of the forensic sciences.

Furthermore, national databases have been instituted to promote forensic data sharing between federal, state, and local entities. These databases include: the ATF's National Integrated Ballistic Information Network (NIBIN), a national database of digital images of spent bullets and cartridge cases that were found at crime scenes or test-fired from confiscated weapons; the FBI's Combined DNA Index System (CODIS), which allows for the electronic comparison of DNA profiles; NIJ's National Missing and Unidentified Persons System (NamUs), which provides criminal justice users a secure, online system to store, share, and compare sensitive case information; and the FBI's Integrated Automated

The New York City Police Department Laboratory's Customer Working Group (NYPD CWG)

In New York City (NYC), forensic testing in almost all disciplines except DNA and toxicology is conducted by the New York City Police Department (NYPD) laboratory. Every day, detectives and police officers submit evidence to the laboratory and communicate regularly with laboratory staff in order to get leads in cases. Similarly, prosecutors request forensic testing and come to know the criminalists who testify at trials about their findings. However, these daily encounters between laboratory personnel, police, and prosecutors do not deal with the broad, systemic policy decisions that affect a laboratory.

In 2007 an irregularity that had occurred several years earlier was uncovered in the controlled substance section of the NYPD laboratory. It was clear that the issue could not be resolved case by case. Instead, an overarching, systematic approach had to be taken. As a result, NYPD created a Customer Working Group (CWG). The CWG consisted of NYPD laboratory leadership and senior decision-makers from the six NYC district attorneys' offices that are serviced by the laboratory.

A CWG is a productive way of meeting the requirements of ISO standard 17025, which creates general guidelines for a laboratory's relationship with its customers. [105, 106] The standard emphasizes the value of ongoing communication and cooperation between the laboratory and its customers in order to clarify customer requests and allow customers to monitor the laboratory's performance. It also instructs laboratories to actively seek customer feedback, incorporate that feedback into ongoing improvement of its services, and inform its customers of nonconformities in the laboratory along with plans for remediation.

The NYPD CWG provided a forum for the group to resolve the issues presented by the irregularity. Prosecutors in the CWG were educated on the scientific aspects of the issue and kept informed about the remediation process. The six prosecutors' offices developed a plan for identifying the affected cases, so that the defense could be notified appropriately and consistently across prosecutors' offices. It quickly became apparent that there was no easy way to identify past cases affected by the issue in which the offending criminalists had testified. The computer tracking systems of the laboratory, the prosecutors, the

The New York City Police Department Laboratory's Customer Working Group (NYPD CWG) (continued)

courts, and the defense did not uniformly list testifying witnesses. As a result of the CWG meetings, the NYPD laboratory now tracks when criminalists go to court and when they testify. In addition to being helpful for future irregularities, the information has proved useful for laboratory management.

Updates on the CWG's progress in dealing with the irregularity were regularly presented to the New York State Commission on Forensic Science.

As the concerns flowing from the irregularity in the laboratory were resolved, it became apparent that there were a wide variety of other issues that could be discussed in a CWG. Some of these included setting priorities for what should be tested, the order of testing, reducing backlogs, introducing new testing methodologies, and changing the format of reports. Backlog issues are particularly well-suited to a CWG. Since a laboratory cannot test every piece of evidence in all cases, it is necessary to triage the work. In the CWG, the NYPD laboratory director discussed a variety of issues including triage protocols, how to maximize the capacity of the laboratory, and improvements to report writing. Unless there is an urgent issue to resolve, the CWG meets twice a year.

Having a preexisting CWG can be especially helpful when a high-profile event occurs, such as the discovery of a nonconformity in the laboratory. Soon after the 2007 matter was resolved, a new problem arose in the NYPD laboratory. Through the CWG, the members were given timely notification of the problem. The laboratory director explained the issue and presented the laboratory's approach to remediation. Based on this information and their earlier experience, the prosecutors were able to efficiently develop a coordinated response to the issue that included providing timely notification to the defense.

The net effect of a CWG is an improved understanding between the decision-makers at the laboratory, police, and prosecutors regarding their respective concerns and priorities. Forensic resources are limited and demands on the system are increasing, thus a collaborative approach to maximizing the benefits of forensic science is essential. A robust CWG is an effective way to reach this goal.

For more information on the NYPD CWG, contact Kristine Hamann, executive director of Prosecutors' Center for Excellence and former co-chair of the NYPD CWG, at khamann@pceinc.org or go to https://www1.nyc.gov/site/nypd/about/about-nypd/contact-us.page.

Fingerprint Identification System (IAFIS), a national fingerprint and criminal history system. BJS Census data from 2009 and 2014 on the utilization of these databases by laboratories show that over two-thirds of publicly funded crime laboratories use NIBIN, CODIS, and IAFIS in some capacity. [62] These national databases have established mechanisms for sharing data among independent organizations for the purpose of broadening the impact of the data being collected. [107-110]

To address the increase in demand for forensic services and expand capacity quickly, many laboratories have outsourced work to private vendors or other public laboratories. In 2014, 38% of publicly funded crime laboratories outsourced one or more types of forensic evidence, up 10% from 2009. A majority of outsourced cases consisted of toxicology analysis and forensic biology casework. [34] However, LSPs noted that even the private laboratories are at full capacity, at times limiting the utility of outsourcing.

Case submission policies are being implemented in laboratories to provide clear evidence submission guidance to law enforcement agencies and prosecutors, which can help reduce workloads of laboratory personnel. Often, excessive amounts of evidence are sent to the laboratory, evidence is sent with insufficient information regarding the type of analysis requested, evidence is poorly packaged or labeled (e.g., inappropriate amount of sample, ambiguous identification, risk of contamination), or case-relevant information is not

communicated, all of which can contribute to unnecessary testing and a waste of resources. [111] In response to the increasing demands for forensic testing, the Phoenix Police Department Laboratory Services Bureau is currently working with law enforcement and prosecutors to set priorities for what evidence should be collected, what evidence should be tested, and in what order. To learn more about this effort, see the sidebar, "Analysis of Laboratory Testing and Outcomes: Illegal Possession of a Weapon Cases."

Case submission policies help a laboratory better understand why the analysis is being requested and encourage the submitting agency to better communicate the scope of the request. For example, some laboratories have established evidence submission policies that limit the number of items or samples that can be submitted to the laboratory in order to encourage evidence testing prioritization and improve the quality of evidence submissions. Other laboratories have developed training mechanisms and guidance for evidence packaging, chain of custody and evidence tracking, and evidence submissions to enhance the quality of evidence being submitted to the laboratories. For instance, the Virginia

Analysis of Laboratory Testing and Outcomes: Illegal Possession of a Weapon Cases

Forensic laboratories are improving and becoming more efficient. Despite these advances, however, laboratories cannot keep up with the increasing demand for forensic testing. Thus, it is important for the laboratory, police, and prosecutors to evaluate the work being done in the laboratory and to set priorities about what evidence should be collected, what evidence should be tested, and in what order.

Without these standards, the laboratory can be pulled in many directions by prosecutors making requests for upcoming trials. For example, a prosecutor often requests DNA and fingerprint testing for a gun as a gun possession trial approaches. The prosecutor wants the testing, even if it yields no usable evidence, so they can demonstrate to the jury that at least an attempt was made to find the evidence. Though this is a laudable goal, fully testing a gun for fingerprints and DNA can take up to 30 hours per gun. This work contributes to backlogs and may deplete laboratory resources from more serious cases where forensic testing could identify a dangerous perpetrator.

The Phoenix Police Department Laboratory Services Bureau is analyzing its data, as well as data from the city's courts and prosecutor, to explore a number of questions about the testing of crime guns. The questions include:

- What part of the gun yields the best results? For example, are fingerprints more likely to be recovered from the trigger or the muzzle of a gun?
- How often does the recovered evidence lead to an identification? For example, if DNA is recovered from a gun, how often does it yield a usable profile?
- What percentage of the laboratory's total work is devoted to lower-level cases such as illegal possession of a weapon versus other types of cases?
- How long before a trial or plea are the tests requested by the prosecutor?
- Are the tests completed before the trials or pleas?
- Do the tests have an impact on the outcomes of the trials or pleas?

Once the information is collected, members of the laboratory, the police, and the prosecutor's office can meet to discuss what testing should be requested and when. Thus, for example, if the data demonstrate that DNA and fingerprints are rarely recovered from the trigger, then the laboratory can stop swabbing the trigger for evidence and save precious resources.

The Phoenix Laboratory is also developing a three-tier system to prioritize its work. Tier 1 cases will get the highest priority and will focus on the most serious cases, such as homicides and rapes. Protocols for Tier 2 and Tier 3 cases are being established to guide when and how evidence will be collected and tested. In some instances, the evidence may simply be collected and preserved for later testing, if needed.

For more information on the Phoenix testing and outcomes study, contact Ben Swanholm, forensic science section supervisor of the Evidence Screening Section, Laboratory Services Bureau, Phoenix Police Department, at Ben.Swanholm@phoenix.gov or go to https://www.phoenix.gov/contactus.

Department of Forensic Science has created guidance documents and made its Evidence Handling and Laboratory Capabilities Guide available on its website. [112] The Houston Forensic Science Center also provides evidence submission guidance on its website. [113]

Similarly, triaging evidence before it enters the laboratory, or even within the laboratory, was regarded by LSPs as an important step in moving towards a more efficient, systems-based process. This requires cross-discipline training and education. Triaging evidence can be done a number of ways, and many agencies have instituted creative, cost-effective ways to triage evidence based on their immediate needs and bottlenecks. For example, the Indianapolis Metropolitan Police Department instituted the Save a Cop program, in which a volunteer uniformed officer, referred to as the Save a Cop liaison, is trained in firearms analysis. Once trained, the liaison can be requested at the scene by a fellow police officer to process collected firearms in a safe and appropriate manner, following standard protocols. The liaison not only ensures that firearm evidence is appropriately collected early in the case, but also performs the basic forensic work at the scene, saving valuable time for the laboratory. For more information, see the sidebar, "Save a Cop Program — Indianapolis Gun Liaison Unit."

Save a Cop Program — Indianapolis Gun Liaison Unit

In 2007, firearm investigators from the Indianapolis Metropolitan Police Department noticed an increase in firearm cases not being filed or successfully prosecuted in court. Prior attempts to improve firearm recoveries by uniformed officers resulted in very limited progress. This led the department to try a new approach called the Save a Cop program.

The program is built on a foundation of volunteer uniformed officers who are committed to improving forensic firearm recoveries and evidentiary documentation. The volunteers receive two days of specialized training on initial firearm investigations, state and federal firearm laws, evidence processing and collection, documentation, and suspect interviews. The training was created with the help of seasoned investigators, prosecutors, and the Indianapolis forensic laboratory. With information collected from these stakeholders, new procedures were developed throughout the department to maximize the potential of the Save a Cop program and minimize the duplication of efforts in firearm investigations.

Each police work shift now has a uniformed, trained Save a Cop liaison. The liaison continues to do routine patrol work but can also be requested to respond to a scene by a fellow officer. At the scene, the liaison provides advice to the officer about lawful gun recovery, such as when a search warrant may be needed to search for a gun. If a gun or ammunition is recovered, the liaison processes the evidence at the scene. While on patrol, the liaison carries the necessary materials for processing a gun and follows a standard protocol. This includes wearing a face mask and gloves while examining the gun for fingerprints and potential sources of DNA. Every step of the processing is documented. The liaison also takes photographs of the gun and packages it appropriately, so it can be sent to the forensic laboratory for further testing.

After the forensic work is completed, the liaison also attempts to interview the suspect and any witnesses, documenting the interaction and any statements with audio or video recordings. Liaisons have a high rate of obtaining statements from suspects. The Indianapolis Office of the Bureau of Alcohol, Tobacco, Firearms and Explosives has also partnered with the Save a Cop program. This collaboration helped to advance more federal firearm case submissions to the U.S. Attorney's Office in the Southern District of Indiana.

One of the benefits of the program is that the first officer on the scene will wait for the liaison and will not touch the gun, so that fewer mistakes are made during the initial stop. If unavailable to respond in person, the liaison can still talk with the on-scene officer by phone, or a member of the police evidence collection team may handle the work instead.

The Save a Cop program has been very successful in collecting useful evidence early in cases. Before this program, the forensic laboratory could take months to get a gun inspected for fingerprints or swabbed for DNA. Now the basic forensic processing evidence work is done at the scene, saving valuable time for

Save a Cop Program — Indianapolis Gun Liaison Unit (continued)

the laboratory. This field processing reduced the turnaround time for the latent print processing of firearms at the Indianapolis Marion County Forensics Agency, from nine months to two weeks. The Indianapolis Metropolitan Police Department Latent Print Unit achieved latent print identification turnaround times of under four business days for most latent prints processed by Save a Cop liaisons. Efforts to replicate this program at different types and sizes of agencies and jurisdictions have demonstrated the need for rigorous program evaluations to determine the most appropriate and effective implementation strategies.

The Save a Cop program has significantly increased the number of cases accepted for prosecution. A homicide case was recently solved when an officer located an abandoned gun and asked for processing by the trained liaison. In the past, the abandoned gun would probably not have been forensically examined. The fingerprints and DNA recovered from the gun provided key evidence in the homicide investigation.

For more information on the Save a Cop program, contact Detective Ron Gray (retired) at saveacop@gmail.com or go to https://www.atf.gov/news/pr/save-cop-program-receives-award.

The Phoenix Police Department instituted an Evidence Screening Section (ESS), where complex cases requiring both friction ridge development processing as well as biological material processing are processed by someone trained in both rather than by two different individuals. The ESS prevented a minimum of 360 hours a year in lost productivity (see the sidebar, "Phoenix Police Department — Evidence Screening Section (ESS)").

In some jurisdictions, prosecutors are involved in the triage process, working closely with investigators, law enforcement, and sometimes laboratory personnel early in the process to decide which items to send to the laboratory, and what types of testing to request (see the sidebar, "Prosecutor Triage of Forensic Evidence").

To complement the triage process and case submission policies, many of the LSPs' agencies have developed a prioritization model. LSPs noted that their laboratories often prioritized by testing rush cases first (e.g., cases involving an imminent court date or immediate threat to public safety), then violent crime cases, then property crime cases. Implementing case submission policies and triaging and prioritizing evidence submitted to the laboratory encourages efficient utilization of limited resources, limits workload demands, and

Phoenix Police Department — Evidence Screening Section (ESS)

The Evidence Screening Section (ESS) of the Laboratory Services Bureau in the Phoenix Police Department is responsible for analyzing physical evidence for the presence of biological material, latent prints, and trace evidence. The ESS also documents and preserves evidence through the use of digital photography and biological collection techniques. ESS staff are proficient in both the development of friction ridge detail and the testing and collection of biological material that may be present on an item of evidence.

Two factors led to the creation of the ESS. The first factor was that items were being submitted to the laboratory for analysis that needed both friction ridge development processing and biological material processing; knives and firearms were the most common items. The second factor was that through its testing, the laboratory found that, outside of some specialized techniques, the earlier friction ridge development processing did not negatively impact the biological material processing and the subsequent DNA analysis. After an internal review of the pilot project, the laboratory found that having items processed by someone trained in both friction ridge development processing and biological material processing was more efficient than having the item go to two different individuals to accomplish the same processing. With four individuals trained in both areas, the ESS saves a minimum of 360 hours a year (90 hours per person per year) in lost productivity.

Prosecutor Triage of Forensic Evidence

The amount of crime scene evidence that can be collected and tested is growing at a rate that exceeds the criminal justice system's capacity. Testing for biological evidence is becoming more sensitive, digital evidence is surging, and technologies for processing a crime scene are rapidly evolving. Since it now may be impractical to recover and test all evidence, it is essential to develop a system for triaging the collection and testing of evidence on individual cases. This can start at the crime scene or soon after.

Crime scenes are processed for forensic evidence in a variety of ways. Though the police will always be involved, some departments also have trained crime scene personnel to recover evidence. On occasion, personnel from the laboratory may be at the scene. This approach can be beneficial, as laboratory staff know how best to collect evidence and what evidence is amenable to testing. However, distance from the scene and limited resources often make it impossible for the laboratory to respond directly.

In some jurisdictions, such as Kansas City, Missouri, prosecutors respond to the scene of all homicides. On occasion, they provide advice about what evidence to collect. Most importantly, soon after the evidence is collected, prosecutors assist with triage decisions. In Kansas City, prosecutors meet with detectives and laboratory personnel and provide valuable input regarding what forensic evidence should be tested and in what order. They know what evidence is most probative and what will be needed for trial.

Some prosecutors' offices, such as those in Camden, New Jersey, and Richmond, Virginia, have forensic triage meetings with the police soon after an arrest but do not initially involve the laboratory.

In Richmond, the prosecutor benefits from access to law enforcement's case management system; prosecutors have electronic access to all photos, evidence collection lists, investigative summaries, surveillance videos, and other evidence within 24 to 48 hours after a shooting. Soon after the violent crime incident, and with the benefit of reviewing the law enforcement investigative materials, the prosecutor meets with the police investigative team. This team includes a forensic investigator who works for the police department and is in charge of crime scene documentation, collecting evidence, swabbing for blood and DNA, etc. The prosecutor and police team then decide what items should be sent to Virginia's state forensic laboratory and what forensic analyses will be requested.

Unfortunately, early triage meetings with prosecutors are not a uniform practice around the country. The testing of evidence is often prioritized much later in the case, through requests from the trial prosecutor based on the timing of an upcoming trial. Also, few prosecutors have protocols in place with laboratories and police outlining the process for prioritizing the testing of evidence so as to make the best use of the laboratories' limited resources.

For more information about the Missouri triage program go to https://www.jacksoncountyprosecutor.com/9/Contact-Us.

For more information about the Virginia triage program go to https://co.richmond.va.us/commonwealth-s-attorney-s-office-contact.

mitigates the backlog. These processes and policies also open lines of communication and encourage collaboration between law enforcement, prosecutors, and the laboratory, further promoting a systems-based approach.

The value of evaluating an organization's internal processes and overall culture cannot be overstated. Many forensic laboratories have used Lean Six Sigma (LSS) methodology to improve their performance by systematically removing waste and reducing variation. A study by NIJ's Forensic Technology Center of Excellence (FTCoE) is currently underway to evaluate the downstream impacts of LSS process implementation within several forensic laboratories. Thus far, implementation of LSS principles has reduced turnaround time by 50% for the participating laboratories, and these laboratories were also able to identify areas in which strategic hires could be inserted to gain the greatest return on investment. The North Carolina State Crime Laboratory experienced similar benefits after implementing

LSS methodology, in addition to engaging in Project FORESIGHT and instituting a forensic science advisory board. The laboratory decreased its backlog by 80% and its turnaround time by 91%, and went from a 60% job vacancy rate to a 10% vacancy rate (see the sidebar, "Transforming Forensic Science Services in the North Carolina State Crime Laboratory").

Additionally, the Palm Beach County Sheriff's Office Crime Laboratory saw a decrease of approximately 33 days in its turnaround time following implementation of an LSS project (see the sidebar, "Palm Beach County Sheriff's Office Crime Laboratory — Improvements at the Laboratory Bench and With the Customers"). Laboratories have found that LSS or similar methodology can help maximize resources, limit waste, and increase efficiency, leading to a decreased workload.

Transforming Forensic Science Services in the North Carolina State Crime Laboratory

In January 2012, the North Carolina State Crime Laboratory (NCSCL) had a 60% job vacancy rate, over 52,500 cases awaiting analysis, and turnaround times exceeding three to four years. Cases were being dismissed due to delayed analysis, and laboratory staff were demoralized. In addition, there were daily negative media stories, the state legislature wanted answers and demanded change, and forensic services had to be outsourced at taxpayers' expense because the NCSCL could not do the job.

The NCSCL was transformed into a high-functioning, ISO 17025-accredited laboratory [105, 106] with all eligible scientists certified by independent bodies. Case inventories have dropped below 10,500 and are still dropping. Laboratory average lead times have reached 92 days (and are still dropping). The vacancy rate is at 10%, one-sixth of what it was in 2012, and the state legislature has appropriated five consecutive years of increasing resources.

In June 2014, laboratory staff were given a clearly defined organizational strategy, including a strategic vision, laboratory mission, values, purpose, and goals, which unified and refocused the entire laboratory. The focus was on four lines of effort: quality, efficiency, collaboration, and transparency/awareness. Leveraging Lean Six Sigma, West Virginia University's Project FORESIGHT, and a highly qualified and dedicated Forensic Science Advisory Board, NCSCL forensic science services were transformed into a highly efficient forensic laboratory.

Palm Beach County Sheriff's Office Crime Laboratory — Improvements at the Laboratory Bench and With the Customers

The Palm Beach County Sheriff's Office (PBSO) serves the largest county in Florida; Palm Beach County has more than 1.4 million people and 28 law enforcement agencies. Furthermore, the PBSO Forensic Biology Unit (FBU) is the county's only serology and DNA service provider. To improve laboratory efficiency and turnaround times given the vast workload, the laboratory engaged in several initiatives that significantly decreased turnaround time, increased transparency, and standardized operations.

In 2009, PBSO used National Institute of Justice (NIJ) grant funds (award number 2009-DN-BX-K261) to build the FBU Biological Processing Laboratory (BPL). Evidence screening can be time-consuming and sometimes unpredictable — the BPL reduced backlog and turnaround time, minimized case research time for DNA analysts, provided preliminary serology results to agencies, and offered a template for other jurisdictions interested in the same changes. Since the BPL started processing evidence in 2012, approximately 20% of all Combined DNA Index System (CODIS) hits at PBSO have come from BPL samples.

The FBU also engaged in a Lean Six Sigma project, implementing a more predictable, stringent system with a team-based approach. After the implementation of the Lean Six Sigma project, the FBU's turnaround time decreased by approximately 33 days in 2017. Additionally, the FBU instituted STRmix™ software for probabilistic genotyping to assist forensic examiners with interpreting DNA profiles and performing

Palm Beach County Sheriff's Office Crime Laboratory — Improvements at the Laboratory Bench and With the Customers (continued)

statistical calculations. The laboratory also developed a radio frequency identification tracking system that allows evidence movement to be tracked throughout the laboratory. Lastly, to further improve forensic analysis at the laboratory bench, iDashboards software was implemented to effectively track and provide metrics for goals and guidance.

PBSO recognized that process improvements with their customers and staff could also benefit the overall operation. PBSO crime laboratory manuals are now available on their website for public access. PBSO also actively seeks and uses customer feedback to make appropriate improvements. For incoming personnel, a new staff orientation form provides new hires with a consistent foundation. A mandatory four-hour workshop on human factors and cognitive bias is provided annually to all staff. Finally, to mitigate discrepancies in case documentation and case evidence, the PBSO property receipt team developed an evidence submission training video, which is now mandatory for law enforcement.

NIJ's FTCoE, led by RTI International, reviewed the implementation of PBSO's BPL project operations from 2009 through 2017 to provide a demonstrable measure of success. Some of the metrics collected during the review (although not all can be directly attributed to the BPL) were:

- Turnaround time decreased from 153 to 111 days.
- Analysts' monthly caseload decreased from 47 to 43 samples.
- PBSO backlog decreased from 679 to 83 cases.
- Items of evidence screened by the BPL increased from 0 to 1,861.
- CODIS entries for DNA profiles increased from 1,186 to 1,291.

The FTCoE subsequently developed a report which presents a roadmap for agencies considering the implementation of a BPL in cooperation with a local DNA testing laboratory in order to make DNA analysis more efficient and reduce case backlogs. This report discusses the importance of understanding leadership roles for the partnering organizations and addresses unexpected challenges encountered during the implementation phase and laboratory testing practices. For further information, see the report: Process and Outcome Evaluation of Forensic DNA Unit Efficiency Improvement Program. [114]

C. Workforce

LSPs identified personnel as a critical need in order to effectively address the workload of forensic laboratories. An analysis of Project FORESIGHT data through 2017 [37] estimates that county, city, and state laboratories need more than 900 full-time employees (FTEs) in order to maintain the current requests submitted to forensic crime laboratories. Employees are also the biggest expense in an organization. Personnel costs accounted for 73% of the $1.4 billion in expenditures reported by publicly funded crime laboratories in 2009. [3] Furthermore, challenges with arduous hiring processes, background investigations, considerable staff turnover, and costs associated with replacing personnel have impacted forensic crime laboratories' ability to achieve optimal staffing to effectively and efficiently address workloads. LSPs also noted that in some disciplines, such as firearms and footwear, vacancies for these positions are not being backfilled. When agencies are not able to work at full capacity, it can have a significant impact on workload and ultimately affect the backlog.

Project FORESIGHT's early work demonstrates an initial methodology for analyzing laboratory performance. [23-25, 101, 115, 116] Research suggests that the level of productivity for any caseload is the most critical component in explaining efficiency in the laboratory. Further analysis of the Project FORESIGHT data can offer each individual laboratory opportunities to accurately estimate the workforce needed to support any level of casework. Researchers have mapped the processes behind some of the staffing issues faced by forensic laboratories, and they have identified FORESIGHT metrics that could help laboratory directors create a working formula to better manage staffing decisions

and issues. [117] Workforce estimates can help laboratories better manage caseloads. The estimates can also provide jurisdictions with critical information when determining ways to use forensic evidence earlier in investigations and with more crime types, and when developing strategies to decrease laboratory turnaround times. [118]

Project FORESIGHT, in cooperation with the FTCoE, has developed the beta version of a "workforce calculator" that any laboratory can use to calculate the optimal workforce required to support a given level of casework within each forensic discipline. Subsequent development of the workforce calculator will examine the associated investment in capital equipment needed to support that level of activity. This calculator is based on the decade of performance data from the most efficient laboratories that participate in Project FORESIGHT. Further model development will identify the characteristics of the high performing laboratories. A laboratory which exemplifies high productivity for its caseload is likely to operate near peak efficient average cost for that level of casework. The goal of the workforce calculator is to allow laboratories to evaluate the production allocations for capital and personnel, while taking into consideration their jurisdictional characteristics — including population, crime rates (violent and property), type of jurisdiction (regional, state, or city levels), and economic market characteristics. [117] This type of tool will help laboratories and their stakeholders proactively develop strategies to prepare for sudden or anticipated shifts in the number and types of laboratory requests.

To establish an efficient operation, laboratory managers need to analyze their staffing models and determine what additional resources are necessary to help their operations meet overall goals and objectives. [119] For example, the Virginia Department of Forensic Science used in-house data to successfully advocate for a laboratory workforce need (see the sidebar, "Virginia Department of Forensic Science — Use of Data To Make a Business Case").

Virginia Department of Forensic Science — Use of Data To Make a Business Case

As a result of the opioid epidemic, the Virginia Department of Forensic Science (VA DFS) was experiencing an almost 10% increase in drug case submissions per year from 2015 to 2017. Not only had the submissions been increasing, but so had the complexity of the samples, the reporting requirements, and the safety measures necessary for personnel working with the controlled substances. These increases had a significant impact on caseloads, backlogs, and turnaround times. When it came time for budget requests, VA DFS presented a business case for the number of new staff needed to address the caseload in the controlled substances section not only in the upcoming year, but over the course of the next 10 years, according to a projection based on current trends. This projection used data from case submissions, backlogs, turnaround times, examiner capacity, and complexity of samples. VA DFS was able to forecast a best-case and worst-case scenario for caseloads and backlogs over the course of the next 10 years. These projections were presented to the governor's office to justify the need for 12 new staff. Additionally, funds for outsourcing casework were requested to continue the workflow while the new hires were being trained. Through this effort, VA DFS received approval to hire all 12 new staff and funds for outsourcing. Without this trend analysis, VA DFS would have been approved to hire only six new staff — half of what it needed — and would have continued to be reactive in addressing increased caseloads each year. This proactive effort helped to ensure that VA DFS is fully staffed and trained to address continuing trends in the controlled substances section over the course of the next decade.

The challenge faced by forensic laboratories is that they tend to be run by individuals who previously held positions in the laboratory, but who lack any formal management or business training. Therefore, creating a business case to systematically assess, and advocate for, the future operational needs of laboratories is difficult for many laboratory directors. [118]

D. Investigative Leads

Forensic evidence can be critical to criminal investigations and prosecutions, however, forensic evidence has historically been underutilized to develop leads early in an investigation and to investigate minor crimes or property crimes (e.g., robbery or burglary). [118, 119] There are significant benefits to generating actionable information from forensic evidence for developing investigative leads. Investigative leads can provide law enforcement with information to potentially advance case investigations and develop actionable intelligence. Investigators can use the information to determine if the results are relevant to the investigation and, if appropriate, may follow with full, confirmatory testing. Often, preliminary testing can demonstrate that no further testing is needed. This can have a tremendous impact on the laboratory, freeing up resources and personnel, reducing turnaround times, and ultimately reducing the backlog. Laboratories have developed ways to institute investigative lead workflows that prioritize casework and improve efficiency. (See the sidebar, "Houston Forensic Science Center Latent Print Workflow.")

Houston Forensic Science Center Latent Print Workflow

In latent print casework, if a latent print from crime scene evidence is not identified to reference prints from initial case suspects (if any), the unknown print may be searched in an Automated Fingerprint Identification System (AFIS) database at the local, state, or federal level. The AFIS search provides a candidate list that may provide "AFIS hits" to record prints retained in the AFIS database. These "AFIS hits" are preliminary AFIS associations made to previously unknown individuals. If no AFIS associations are made, the latent print can be registered to the Unsolved Latent Database. Once registered, the unsolved latent prints are automatically compared with any new fingerprint records entered in AFIS by the AFIS system. In conventional AFIS latent print workflows, reference prints from any new candidates that hit in AFIS are compared by the examiner to all original unidentified latent prints from the case, which is also referred to a second examiner to verify the results. Performing these comparisons can be a long and tedious process depending on the amount of unsolved latent prints in a given case.

In early 2015, the Houston Forensic Science Center (HFSC) began a pilot program of a new latent print workflow to allow the laboratory to better use its time and resources while also demonstrating clear and immediate value to its stakeholders by providing the right answer at the right time to advance case investigations and develop actionable intelligence. HFSC decided to launch the pilot using any Unsolved Latent Matches (ULMs) returned from prior cases to see if it would make that workflow process more efficient. Rather than continuing with complete and lengthy comparisons, the new HFSC workflow included a step to halt the examination process once the initial examiner determined a "hit" or preliminary AFIS association within AFIS. At that point, the examiner issued the preliminary findings to the requestor in the form of an "investigative lead report." This report provided the investigator with the name of an individual and the unique local, state, or federal identifier. The investigator could then use this preliminary information to determine whether the individual listed might be pertinent to the investigation; if so, the requestor could then ask for a full, confirmatory latent print comparison. The investigative lead reports convey in clear language that the preliminary association was not an official identification or a confirmation. Once a request for a full comparison was received, the latent print examiner compared all latent prints in the case to the individual listed in the AFIS results, the findings were verified by a second latent print examiner, and an official comparison report was issued.

After the new workflow launched, few requests were received for full comparisons of ULMs. Encouraged that the workflow was functioning as designed, HFSC extended the process to property crimes cases, which constitute more than 80% of requests received by the HFSC Latent Print Section. Many latent prints developed from property crimes are found on vehicles and building spaces. In many instances, latent prints collected from these locations belong to someone who had legitimate access to the property, such as a homeowner. These latent prints may have little or no probative value.

Once all stakeholders understood the goal of the investigative lead reports and the policy constraints, the latent print section implemented the new investigative lead workflow for all property crimes by November 2015. In May 2016, the Houston Police Department's violent crime divisions, including heads from the

Houston Forensic Science Center Latent Print Workflow (continued)

homicide, robbery, and special victims units, unanimously decided to use the investigative lead workflow. By July 2016, the latent print section was using the workflow for all crimes that had no suspects.

The impact on laboratory workload and case reporting was astounding. Between July 2016 and November 2017, the latent print section issued 1,086 investigative lead reports, which accounted for approximately one-third of the latent print reports issued. A review of the investigative lead reports metrics found that only 173 reports resulted in a subsequent request for a full comparison and official confirmation report. This indicated that the traditional, time-consuming workflow was not needed 84% of the time. Investigators who had previously waited weeks, and sometimes months, for any information on latent prints were receiving usable data within days. Able to more quickly process incoming cases — and eliminate unnecessary work by not doing full comparisons on nonprobative evidence — HFSC's latent print section has been better able to focus time and resources on its backlog. Since the inception of the investigative lead workflow to include all crime types in June 2016, the backlog has dropped from more than 3,600 cases to just over 1,700. This workflow also provided an increased capacity for the HFSC Latent Print Section. Starting in May 2018, the HFSC Crime Scene Unit started collecting more than 400 lift cards per month, resulting in 80-100 leads per month (including 241 leads in the first two months of 2019), which would not have been possible without the new workflow.

Using investigative lead reports requires better communication with stakeholders on their advantages and limitations, but the workflow ultimately provides stakeholders with information much more quickly while also increasing laboratory efficiency.

For more information on enhancing latent print workflows, contact: Tim Schmahl, Latent Print Section Manager at the Houston Forensic Science Center, http://www.houstonforensicscience.org/contact-us.php.

Developing investigative leads requires investigators, laboratory personnel, and prosecutors to engage in a systems-based approach, collaborating closely and transparently on forensic cases. This level of collaboration can yield considerable benefits on workloads for all of the forensic service providers involved, and ultimately help them process cases in a more efficient and timely manner to better serve justice. [61] The NIJ Cold Case Working Group can also be a source for agencies interested in engaging with forensic science service providers to fully employ available, and relevant, forensic practices to generate actionable intelligence [120] (see the sidebar, "The National Institute of Justice's Cold Case Working Group (CCWG)").

The National Institute of Justice's Cold Case Working Group (CCWG)

From 2005 to 2014, the National Institute of Justice's (NIJ) Solving Cold Cases With DNA program made over 200 awards (approximately $80 million) to states and units of local government for identifying, reviewing, and investigating Uniform Crime Report (UCR) Part 1 Violent Crime "cold cases" that have the potential to be solved through DNA analysis. These funds could also be used to locate and analyze biological evidence associated with these cases. In late 2015, NIJ established a Cold Case Working Group (CCWG) to develop the *National Best Practices for Implementing and Sustaining a Cold Case Investigation Unit*, a best practices guide to assist law enforcement agencies in creating a mechanism for addressing the cold cases in their jurisdictions. The CCWG was composed of subject matter experts from academia, law enforcement (state, local, urban, rural, and federal), ME/C offices, prosecution, victim advocacy, and forensic laboratories. In this best practices report, the CCWG: 1) determined best practices for creating and sustaining a cold case unit; 2) provided a list of resources for cold case units; 3) identified innovative forensic technologies which can be applied to cold case investigations; and 4) determined the best way for NIJ to provide support to the community.

Data from the FBI's Uniform Crime Reporting (UCR) program demonstrate that the cold case clearance rate had declined to less than 60% in 2016. The CCWG identified several promising practices that can support cold case investigations, such as using nontraditional forensic analysis (e.g., novel DNA

The National Institute of Justice's Cold Case Working Group (CCWG) (continued)

approaches and non-DNA technology, such as pollen and isotope analysis for geolocation attribution), incorporating missing persons and unidentified persons data, and including volunteer professionals from outside the department to review case files. These volunteers can provide a new set of eyes and alleviate the workload of detectives. This strategy has demonstrated successes in Charlotte, North Carolina, and Tulsa, Oklahoma, with professionals who possess prerequisite skills and are properly vetted with nondisclosure agreements. Other agencies have implemented this practice with academic researchers and graduate students as volunteers. Cold case units also increase the perception of public safety and may act as a deterrent for criminal activity.

It is important that law enforcement agencies conduct their own needs assessments to determine the specific needs of their workforces and the needs for their forensic services infrastructure in order to provide the cold case unit with adequate time, resources, and experienced personnel to successfully pursue investigative and forensic leads. For more information, see the NIJ Report, *National Best Practices for Implementing and Sustaining a Cold Case Investigation Unit* [120], at https://www.ncjrs.gov/pdffiles1/nij/252016.pdf .

V. Infrastructure and Equipment

Needs:

- The ability to respond reliably and efficiently to casework requests by increasing workforce and purchasing resources, new technology, and equipment.
- The ability of a facility to procure new technologies and equipment and implement them in the laboratory workflow in a timely fashion.
- Appropriate and reliable security measures to support the increased utilization of electronic data submissions, storage, and sharing, both internally and externally with other forensic science service providers.

Challenges:

- Laboratories' physical capacity and infrastructure are maximized and/or outdated.
- State and local procurement processes are arduous and protracted.
- Validation of equipment is time-consuming.
- Some organizations lack appropriate information technology (IT) services and solutions for forensic data management and storage.
- Lack of collaboration between vendors, laboratories, and IT service providers to address forensic community needs. Implementation of cybersecurity measures to ensure data integrity and security.

Promising Practices:

- Develop mechanisms to share validation methods between forensic science service providers, laboratories, IT service providers, and vendors and collaborate to implement a customized, sufficient, and reliable security infrastructure.
- Strategic application of NIJ's Paul Coverdell Forensic Science Improvement Grants, and use of lease programs available to public agencies to support the acquisition of costly new instrumentation and technologies.
- Use of guidance documents and funding resources to successfully design, construct, or renovate a laboratory, with a focus on increasing process efficiency.

- Optimization of the provision of forensic services through innovative collaborations, such as sharing agreements, consolidation of services, and regionalization of services.

A. Infrastructure

To sufficiently address the increase in demand for and complexity of forensic services, listening session participants (LSPs) and stakeholders reported that forensic laboratories need to address the physical limitations of their facilities. In addition to lacking physical space, some facilities are outdated and do not have the electricity or mechanical capacity to accommodate new technologies and equipment. These facilities will require new laboratory space, or at the very least renovations to their existing laboratory space to house new technologies, equipment, and personnel. This section discusses both infrastructure and equipment needs for forensic crime laboratories, and the infrastructure and equipment needs specifically related to the medical examiner and coroner (ME/C) system will be discussed in the Medical Examiners and Coroners section.

To address infrastructure needs, many LSPs have relied heavily on a handbook published in 2013 by a working group sponsored by the National Institute of Standards and Technology in coordination with the National Institute of Justice (NIJ), titled *Forensic Science Laboratories: Handbook for Facility Planning, Design, Construction, and Relocation*. [121] This handbook provides guidance to forensic laboratory directors on how to more effectively achieve three objectives related to laboratory design, construction, and renovation projects: 1) maximize organizational efficiency; 2) ensure the economical expenditure of resources; and 3) develop a safe, secure, and well-designed facility. The handbook includes four sections on the planning, design, construction, and relocation of a forensic science laboratory, and each section provides project team roles and responsibilities within the particular process stage; process diagrams and narrative descriptions; tools to support each project phase; and an actions checklist. Not only does the handbook address general laboratory design and administration, it also discusses recommendations for laboratory sections such as controlled substances, toxicology, firearms/toolmarks, trace analysis, forensic biology/DNA, latent prints, questioned documents, digital forensics, photography, and evidence management. [121] To complement this handbook, NIJ's Forensic Technology Center of Excellence (FTCoE) developed guidelines and checklists for Lean Facility Design (LFD), which focuses on aligning employee satisfaction, process efficiency, and product quality with customer satisfaction. [122] This document, *Development of a Lean Facility Design Roadmap for Design-Bid-Build Forensic Facilities*, integrates with the aforementioned *Forensic Science Laboratories: Handbook for Facility Planning, Design, Construction, and Relocation* and presents an LFD roadmap for planning and constructing 21st century Design-Bid-Build forensic facilities. (See the sidebar, "FTCoE Provides a Case Example for Conducting a Forensic Facility Needs Assessment Using Lean Facility Design.")

FTCoE Provides a Case Example for Conducting a Forensic Facility Needs Assessment Using Lean Facility Design

Lean Facility Design (LFD) is a strategy that optimizes the logical and systematic flow of work, people, and information through a facility. This strategy can ultimately improve work processes; ensure quality products; and determine the configuration of physical spaces, such as forensic facilities. The National Institute of Justice's Forensic Technology Center of Excellence (FTCoE) collaborated with the Midwest Forensics Resource Center to conduct an LFD needs assessment at the Broward County Sheriff's Office in Fort Lauderdale, Florida, as a case example of operational needs assessment in a forensic facility. This 2018 project evaluated the *Lean Facility Design Roadmap for Design-Bid-Build Forensic Facilities* that was developed by the FTCoE in 2016. [122]

FTCoE Provides a Case Example for Conducting a Forensic Facility Needs Assessment Using Lean Facility Design (continued)

Using an LFD approach means eliminating all steps that do not add value to a process. The LFD principles adapted for a forensic context include: [123]

- Identify and focus on the customer's needs.
- Assess laboratory processes to identify and address wasteful steps.
- Manage the workflow and standardize processes around best practice.
- Manage by fact and reduce variation.
- Continuously strive to achieve optimal process flow.

Traditionally, a facility needs assessment involves completing surveys, conducting interviews, and touring comparable facilities. This project detailed the steps for using an LFD approach to conduct a needs assessment in a forensic facility, which requires the commitment of personnel and an external team specializing in lean thinking. The six stages of the LFD process — situational analysis, current-state practice, ideal-state operation, future-state practice, future-state planning, and closing the loop — are critical in assessing a laboratory's process flow. These stages can be easily modified and adapted to new tasks, goals, and objectives. While the outcome of a needs assessment will vary by agency, the same lean thinking strategies can be applied to increase efficiency relevant to each agency's needs identified in an LFD assessment.

In the case of the Broward County Sheriff's Office, an LFD assessment helped to identify key process flow issues and develop solutions for improving efficiency. Building a new facility will eventually be necessary for the sheriff's office to fully optimize operational processes and address staffing concerns; however, the agency has taken a stepwise approach in the meantime to improve efficiencies by implementing LFD concepts. The full report is available at: https://forensiccoe.org/report-development-of-a-lean-facility-design-roadmap/.

B. Equipment

According to FORESIGHT data, many laboratories are delaying capital expenditures in order to meet immediate needs by shifting resources to personnel and consumables. [37] In the short run, the laboratory will experience more throughput as capital expenditures are delayed in favor of higher expenditures for personnel and consumables. Some laboratories have achieved immediate gains from reallocating funds from capital to personnel according to the 2017 FORESIGHT data. The long-term penalty will be experienced via higher investment costs for equipment, maintenance, and upkeep in the future at the expense of lower expenditures for personnel and a concomitant decline in output. The estimated gap in the allocation of funding for capital and personnel suggests that the additional funds needed to maintain the ideal mixture of capital and personnel are approximately $50 million for the FORESIGHT laboratories. It is important to note that the ratio of capital expenditures to personnel expenditures will vary across areas of investigation due to differences in the capital intensive nature of the discipline.

Furthermore, laboratories are expanding their testing capabilities, which requires specialized instrumentation, and laboratory information management systems have become more critical for laboratory case tracking. [63] These new, sophisticated instruments and evidence tracking systems can be very expensive and can have a limited lifetime of support by the vendor. However, they remain critical for operating a forensic laboratory and processing casework in an efficient, reliable, and contemporary manner, such as in the implementation of Rapid DNA (see the sidebar, "Rapid DNA").

One of the challenges cited by LSPs in regard to equipment is the state and local procurement process. The procurement process can be arduous, and it may take years to

Rapid DNA

What is Rapid DNA? Rapid DNA (RDNA) is new technology that will allow for on-site development of a DNA profile through the use of an automated instrument. Once DNA is collected from an arrestee's cheek swab, RDNA will allow the process of developing the DNA profile — including searching the national Combined DNA Index System (CODIS) — to be completed in less than two hours. Traditional DNA analysis requires samples to be transported from booking stations to forensic laboratories, and samples can often take weeks or months to process.

Why use RDNA? When implemented in booking stations, RDNA will allow for real-time CODIS registration and linking an arrestee to unsolved crimes in the DNA Index of Special Concern (DISC), effectively a DNA watch list of unsolved homicide, terrorism, kidnapping, and sexual assault cases. RDNA will be performed at booking stations in jurisdictions with laws that allow DNA analysis upon arrest.[1] If an immediate match occurs in DISC, an unsolicited DNA notification message will be transmitted through the National Law Enforcement Telecommunications System (NLETS) to the arresting, booking, and investigating agencies. The NLETS message will be similar to a "Wants and Warrants" notification and will be received and processed like regular NLETS notifications by recipient agencies.

What are the benefits of RDNA?

- *Increased public safety.* RDNA will allow for arrestees to be identified as putative perpetrators of crimes from across the country while in the booking station. The ability to detain these individuals in connection to the unsolved crimes is a tremendous opportunity to enhance public safety.
- *Increased efficiency.* Through the use of RDNA instruments, state, local, and federal agencies will be able to link an arrestee to a violent felony while still in custody, conserving investigative resources.
- *Access.* CODIS software already has the modifications needed to allow all state and local agencies to nominate DNA crime scene profiles into the DISC. Therefore, states without arrestee laws benefit from RDNA through this nomination process that allows its crime scene profiles to be searched against the arrestees in another state, even though they are not authorized under state law to use RDNA for arrestee bookings.

What will RDNA's impact be? The RDNA workload will depend on how many arrests are processed through the booking stations and what configuration of RDNA equipment they use. As of July 2019, RDNA equipment has not yet been approved by the FBI for booking station use. Pilots are planned for 2019 in Arizona, California, Florida, Louisiana, and Texas and in federal booking stations. Following these pilots, the FBI will issue booking station standards and procedures.

What resources are needed for RDNA? At a minimum, each RDNA booking station will need:

- RDNA instruments and cartridge supplies. (Five DNA samples can be processed per cartridge; estimated $500,000 to establish RDNA at a site).
- Space for collection of DNA and RDNA processing. The RDNA machine does not have to be in close proximity to LiveScan fingerprint equipment.
- Two full-time staff members for collection and processing operations.
- Changes to the IT infrastructure to support RDNA processing.

RDNA technologies must comply with applicable law and the FBI's quality assurance standards and must follow specific policies and procedures identified by the FBI. For more information, see https://www.fbi.gov/services/laboratory/biometric-analysis/codis/rapid-dna.

[1] States that allow DNA collection at arrest or booking are: AL, AK, AZ, AR, CA, FL, KS, LA, MI, MO, MS, NJ, ND, OH, SC, and SD. RDNA testing of samples is also allowed at the federal level.

receive equipment, which can impact laboratory operations. To ease the burden, some forensic science service providers have turned to state and federal programs. The Virginia Department of Forensic Science has utilized the state's Master Equipment Lease Program, which provides a financing option for equipment (see the sidebar, "Master Equipment Lease Program (MELP)").

Master Equipment Lease Program (MELP)

In fiscal year 2017 the Virginia Department of Forensic Sciences (VA DFS) needed to procure four new instruments for its toxicology section to keep up with increasing casework demands. However, the cost of these new instruments was approximately $2.2 million, which could not be covered under the current budget. VA DFS explored using the Virginia Master Equipment Lease Program (MELP) for assistance with purchasing this equipment. The Virginia MELP is run through the Virginia Department of Treasury and has typically been utilized by the Virginia State Police for purchasing new vehicles. The Virginia Department of Treasury procures a line of credit from financing companies to finance equipment, with terms ranging from three to 10 years. The Virginia MELP also ensures that all Virginia agencies obtain consistent and competitive credit terms for financing equipment and energy efficiency projects. Through this program, VA DFS was able to finance the four toxicology instruments for a period of seven years, beginning in 2018, at $350,000 per year. VA DFS was appropriated $350,000 annually for this purpose.

MELP is not unique to Virginia. Most states have similar MELP programs for state agencies. Forensic science service providers can reach out to their state's MELP programs for more information on using MELP funds to purchase needed equipment.

Additionally, NIJ's Paul Coverdell National Forensic Science Improvement Grants program (Coverdell program) provides funding to states and units of local government to improve the quality and timeliness of forensic science and ME/C services (see the sidebar, "The Paul Coverdell Forensic Science Improvement Grants Program").

Coverdell program funding may also be used to upgrade, lease, or purchase forensic laboratory or ME/C equipment and instrumentation. However, despite Coverdell program funding, there are too few programs available overall to address equipment needs for the wide array of forensic disciplines. The Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) has a different approach to equipment procurement; its National Integrated Ballistic Information Network (NIBIN) is accessible through machines on loan to local and state police agencies around the nation. [124] Through the ATF's model, the equipment is free of charge and available based on need. This model not only alleviates procurement issues, it also yields consistent information across laboratories, which provides opportunities for cross-laboratory collaboration and problem solving.

Equipment validation — another challenge cited by LSPs — is a critical part of increasing laboratory capacity, particularly when installing new instrumentation. According to ISO/IEC standards 9000 and 17025, validation includes confirmation, through the provision of objective evidence, that the requirements for a specific intended use or application have been fulfilled. [105, 106, 125] This is the process of demonstrating that a laboratory procedure or instrument is robust, reliable, and can reproduce results in the hands of the personnel performing the test in that laboratory. The validation process is extremely time-consuming, costly, and not well understood by those outside the laboratories. It takes personnel away from the laboratory bench for a significant amount of time, which can impact casework and turnaround times.

Across the country, laboratories are developing methods to validate new instrumentation and equipment. LSPs expressed that a mechanism to share validation methods could save cost and time in laboratories, and ultimately provide more time for forensic personnel to focus on addressing their casework. Sharing mechanisms could also promote partnerships and innovative collaborations between forensic service providers and stakeholders, such as consolidation or regionalization of services and sharing agreements or memoranda of

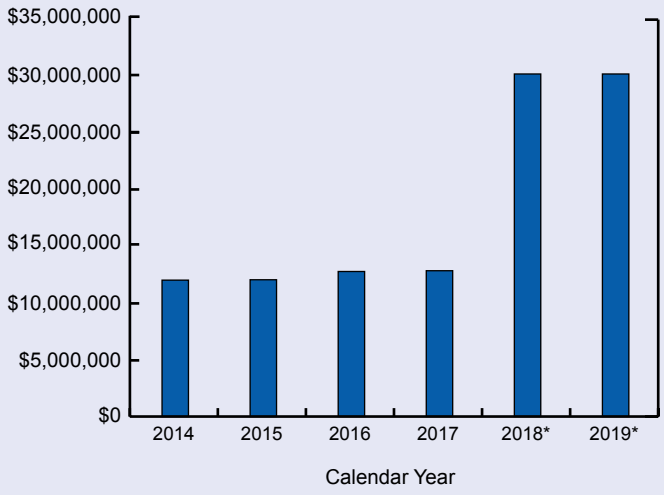
The Paul Coverdell Forensic Science Improvement Grants Program

The National Institute of Justice (NIJ) Paul Coverdell Forensic Science Improvement Grants Program (Coverdell program) awards grants to states and units of local government to improve the quality and timeliness of forensic science and medical examiner/coroner (ME/C) services.[1] Funds received under the Coverdell program can be used for the following purposes:

1) To improve the quality and timeliness of forensic science or ME/C office services
2) To eliminate a backlog in the analysis of forensic science evidence
3) To train, assist, and employ forensic laboratory personnel and medicolegal death investigators as needed to eliminate an evidence backlog
4) To address emerging forensic science issues and technology
5) To educate and train forensic pathologists
6) To facilitate accreditation of ME/C offices and certification of medicolegal death investigators

The types of expenses that may be paid with Coverdell program funds include: personnel, computerization, laboratory equipment, supplies, accreditation, education, training, certification, facilities, and administration.

Coverdell Program Enacted Funding



* $17 million made available to target challenges of the opioid crisis

[1] States (including territories) and units of local government may apply for Coverdell funds. States may be eligible for both "base" (formula) and competitive funds. Units of local government within states may be eligible for competitive funds and may apply directly to NIJ. Any state application for funding must be submitted by the Coverdell State Administering Agency (SAA). (Other interested state agencies or departments must coordinate with their respective SAAs).

understanding. For example, universities could perform the initial validation and then work with laboratory staff to translate these processes to their laboratory settings (see the sidebar, "Marshall University's Technical Assistance Program (TAP)," for more information).

C. Information Technology

As forensic science operations have moved towards more digital environments, cybersecurity and IT solutions and support have become more of a necessity. Laboratories must contend with increasing quantities of digital information and must determine how to manage, archive, and curate this data to manage casework effectively and facilitate data access

and data sharing with the appropriate stakeholders. Laboratories may even spend years modifying their digital environments due to challenges with data migration, compatibilities, and building more customized functionalities to meet the evolving needs of the forensic community. Therefore, robust IT solutions and scalable data storage can have a dramatic effect on casework efficiencies and workflows, and laboratories have demonstrated an interest in moving toward cloud-based solutions to address data storage and computing needs. Cloud-based storage of evidence could also facilitate casework reviews, thereby increasing workload efficiencies.

Data integrity is also critical in forensic quality assurance, and the need for increased data security measures is considerable. LSPs, like all government entities, have experienced hacking and phishing attempts. Sometimes laboratories have gone offline for periods of time in order to protect their data. These breaks in service are disruptive to the workflow. Some LSPs noted that their operations are so tied to computers that network outages have a direct effect on the case backlog. Having the IT resources in place to quickly respond to network threats as well as day-to-day network and computer issues is important to an operation's workflow. Unfortunately, not all facilities have the luxury of in-house IT services.

VI. Accreditation and Quality Management

Needs:

- More available training on the accreditation process.
- Recognition that different forensic science disciplines may require different accreditation standards.
- Additional support and resources for agencies seeking accreditation.

Challenges:

- Accreditation can be costly to agencies. Costs include the need to provide education and resources/personnel for advancing quality assurance activities and participation in accreditation programs. These costs can be particularly burdensome to smaller agencies.

Promising Practices:

- Partner with accredited laboratories for resources.
- Have accredited laboratories serve as mentors for those seeking accreditation.

Accreditation assesses a forensic laboratory's capacity to generate and interpret results in a particular forensic discipline and helps to ensure ongoing compliance with industry and international standards. An independent accrediting body assesses and monitors the quality of the laboratory's management system by examining factors that include staff competence, method validation, appropriateness of test methods, calibration and maintenance of test equipment, testing environment, and quality assurance data. Accreditation is one way to increase the quality of work and advance professional accountability and transparency to the benefit of all forensic science stakeholders while increasing public trust. [125] According to a Bureau of Justice Statistics (BJS) Census of Publicly Funded Forensic Crime Laboratories (Census), 88% of the nation's 409 publicly funded forensic laboratories were accredited by a professional forensic science organization as of 2014, compared with 82% in 2009 and 70% in 2002. [63, 93, 98] Nearly all (99%) state-based laboratories were accredited in 2014, and some agencies' forensic units (e.g., crime scene units) are seeking accreditation under ISO/IEC 17020 (Conformity assessment — Requirements for the operation of various

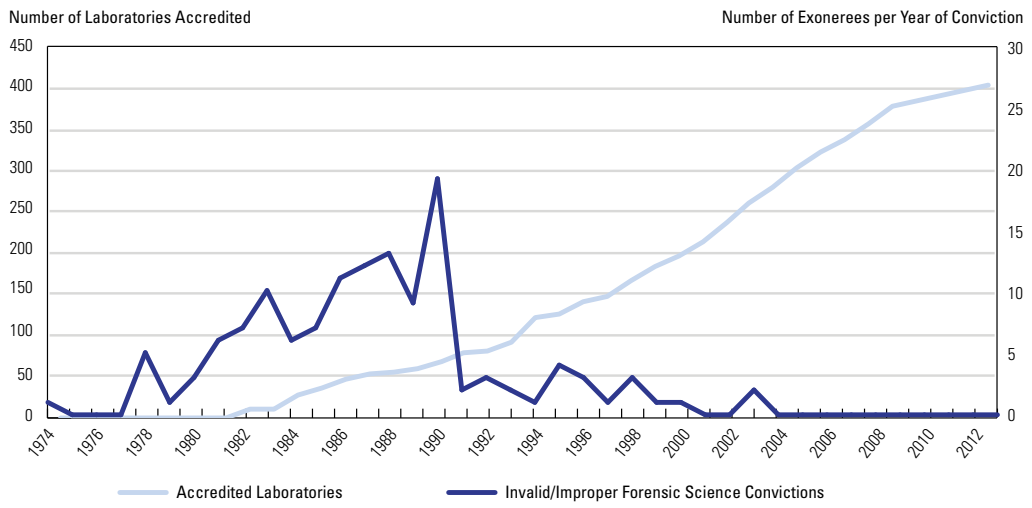
types of bodies performing inspection) or ISO/IEC 17025 (General requirements for the competence of testing and calibration laboratories). [105, 106, 127] This significant rise in the number of laboratories accredited over the past two decades and the numerous checks and balances provided through the accreditation process may "help to answer why there has not been a significant number of erroneous convictions related to forensic science since the mid-1990s" (see Figure 3). [128]

As the BJS Crime Laboratory Census data demonstrate, accreditation is now a routine practice among public crime laboratories. Accreditation is facilitating the provision of consistent forensic services across the United States, strengthened by the development of forensic-specific supplemental requirements by accrediting bodies and international standards organizations. In 2015, the U.S. Department of Justice (DOJ) reaffirmed the value of accreditation by committing that all of its traditional forensic laboratories will continue to maintain accreditation. DOJ also encouraged accreditation of state and local forensic laboratories. The increased rate of accreditation demonstrates the community's response to the 2009 National Academy of Sciences (NAS) recommendations on accreditation and establishment of quality assurance and quality control procedures. [30] However, as noted by listening session participants (LSPs) and in several sources, some crime laboratories and many small forensic units that practice a limited number of disciplines still face discipline-specific, budgetary, staffing, and facility constraints. [13, 21, 61, 129] BJS Census data demonstrate that the lowest accreditation participation levels occur at smaller laboratories (staffed by nine or fewer full-time employees) and laboratories operated at the county or municipal levels.

According to LSPs, some agencies may not feel that accreditation is the highest priority or a reasonable investment if not mandatory or incentivized. LSPs noted that securing funding sources for accreditation can be a challenge, and some agencies may not want to divert time and workforce efforts from casework.

Leadership should recognize that there are ancillary costs and responsibilities associated with implementing quality assurance programs and accreditation, to include training, development and implementation of quality assurance processes, access to resources, and dedicated personnel or ancillary duties (e.g., quality manager). (For more information, see the Personnel section of this report.) Accreditation efforts may be addressed through the National Institute of Justice (NIJ) Coverdell program (see the sidebar, "The Paul Coverdell Forensic Science Improvement Grants Program") for more information), which allows states and units of local government to apply for funds to prepare for laboratory accreditation and to cover the fees charged by the accrediting bodies. [96] However, Coverdell program funding is limited and goes toward a variety of forensic purposes besides accreditation. While most agree that wider accreditation is the ultimate goal, LSPs strongly encouraged the field to properly and clearly define who needs to be accredited so agencies understand the expectations. Additionally, agencies — regardless of their size or structure — can take initial steps to adopt accreditation's culture of quality through implementing written procedures for evidence, written reports, technical and administrative review of reports

Figure 3. Number of Laboratories Accredited Per Year vs. Number of Exonerations (Year of Conviction)



Note: Data are based on 133 cases of wrongful conviction listed by the National Registry of Exonerations, 1974-2016.
Source: Wrongful Convictions and DNA Exonerations: Understanding the Role of Forensic Science (Exhibit 5) [128]

and supporting records, testimony monitoring, note-taking, written technical procedures, training programs, proficiency testing, and corrective and preventive action processes. [130]

In 2018, DOJ posted quality management system documents online to promote the scientific value of transparency and enhance knowledge of DOJ forensic policies and practices. These documents include quality assurance measures, laboratory policies, and standard operating procedures for testing and analysis, as well as summaries of internal validation studies for forensic methods and techniques that are currently used by DOJ laboratories. [131] Several state and local crime laboratories have also posted quality management system documents online for the public, which can help promote the implementation of quality controls. Examples include: Houston Forensic Science Center, Virginia Department of Forensic Science, Idaho State Police, Washington, D.C. Department of Forensic Science, and the Austin Police Department. [132-136] Accredited laboratories could also mentor smaller agencies to develop quality program implementation strategies and overcome accreditation misconceptions.

DOJ also recognized that accreditation in some disciplines, such as digital forensics and medicolegal death investigation, could be examined separately from accreditation in other traditional forensic disciplines given the differences in their forensic practice. [137, 138] The Digital and Multimedia Evidence and Medical Examiners and Coroners sections of this report will discuss specific accreditation requirements for these disciplines in greater detail.

VII. Medical Examiners and Coroners

Needs:

- Resources and partnerships to strengthen the consistent provision of medicolegal death investigation (MDI) services and the application of MDI standards and best practices for over 2,000 medical examiner and coroner (ME/C) offices across the United States.
- Resources and strategies to address the national shortage of trained, board-certified forensic pathologists that threatens the quality and consistency of MDI services, underscored by deaths attributed to the opioid crisis.
- Recruitment and retention initiatives to build and maintain a national MDI workforce.
- Increased training, certification, and staffing resources to strengthen the MDI workforce and personnel who provide ancillary services that support the MDI and forensic pathology workload (e.g., autopsy technicians, pathology assistants, forensic radiologists, and forensic photographers).
- Case management systems and information technology (IT) infrastructure for ME/C record keeping, data/information sharing between offices, and data interoperability to facilitate coordination of MDI data with public safety, public health, and critical incident stakeholders at the local, state, and federal levels.
- Development of an MDI research culture.

Challenges:

- Levels of staffing, budgets, resources, and supplies are too inconsistent to ensure that death investigations are of the same quality across the United States.
- The opioid crisis is taking a tremendous toll on the already strained, understaffed, and under-resourced MDI workforce.
- MDI exists at the nexus of public health and the justice system. It arguably shares more similarities with public health needs, yet there is no principal federal entity charged with strengthening the ME/C system across the United States, and no dedicated grant program to advance the standard and consistent application of MDI services.

Promising Practices:

- Regionalization of ME/C offices, or consolidation of MDI services and innovative collaborations, such as sharing agreements with forensic laboratories, can expand the scope and impact of MDI services and resources.
- Recruitment incentives to enter the forensic pathology profession (e.g., state- and local-sponsored student loan repayment programs, competitive salary and benefits).
- Strategic partnerships to increase engagement with medical students (to promote forensic pathology career opportunities) and with forensic science academic program candidates and graduates (to recruit for MDI workforce ancillary positions).
- ME/C access to public health and public safety information systems (e.g., prescription drug monitoring programs, fingerprint databases) to support timely and informed MDI decision-making.
- Emergence of ME/C forensic epidemiologist positions that are dedicated to analyzing MDI data to identify trends, contribute to fatality review teams, and inform public safety and public health initiatives.
- Utilization of the National Institute of Justice (NIJ) National Unidentified and Missing Persons System (NamUs) to support missing persons investigations and the identification of human remains.

Medical examiners and coroners investigate deaths that are sudden, unexpected, unusual, suspicious, or violent, and deaths in which there is no attending physician. While some of these deaths are related to crimes, the majority relate to diseases or public health-related issues. Certain accidental deaths can impact both public health and public safety, such as cases of drug overdoses or driving under the influence. ME/C offices provide MDI services almost entirely at the state and local levels, and the ME/C system is composed of various types of death investigation systems, as determined by state laws and jurisdictional boundaries. These systems include state-, county-, and district-based medical examiner, coroner, or mixed systems. [30, 139, 140]

MDI services include death scene investigation and evidence collection, forensic autopsy, forensic toxicology, review of medical records, forensic radiology and specialized imaging techniques, histology, and microbiology. ME/C offices play a critical role in identifying potential crimes, and even suspects, through the examination of injuries and death scenes. ME/Cs also help identify decedents, which can be crucial for solving missing person cases. Comprehensive testing can help distinguish suspicious deaths from those that are due to natural causes and provide further insight into deaths that may be unexplained or otherwise certified as undetermined. The emergence of testing for hereditary diseases (known as "molecular autopsy") has broadened the scope of testing services procured by and through ME/C offices, particularly in cases of sudden deaths in infants or the young. [141-144]

However, the availability and application of MDI services can vary greatly between and within states, just as ME/C personnel training and qualifications vary from state to state. [12, 140, 145-147] Through the death investigation process, ME/C offices determine causes and manners of death and provide critical information to the public health and justice systems by documenting and reporting on postmortem findings, and by providing expert

witnesses. [148] MDI data, when analyzed in aggregate, are critical for developing public health and safety initiatives and informing policymakers. These data are important for identifying trends or outbreaks at the local, state, regional, and national levels, particularly in light of increased drug overdose deaths attributed to the opioid crisis and emergence of other drug threats. [7, 149-151] See the section on Opioid Crisis and Emerging Drug Threats in this report for more information.

The needs of a given ME/C system should be assessed based on the specific jurisdiction's geographic size, population, and total number of deaths, as well as local MDI requirements. The 2004 Bureau of Justice Statistics (BJS) Census of Medical Examiner and Coroner Offices (CMEC) identified approximately 2,000 ME/C offices operating in the United States. [12] Of this total, 1,600 were coroner offices (80%) and 400 were medical examiner offices (20%). Two-thirds of the ME/C offices (1,361, or 68%) served populations of less than 50,000. [103] Recent estimates put the number of ME/C offices closer to 2,400. [10, 30, 32] The BJS CMEC estimated that ME/C offices employed 7,320 full-time equivalent personnel as of 2004. For comparison with the overall forensic workforce at this time, BJS estimated that the overall forensic workforce in 2005 comprised 11,900 full-time equivalent personnel employed by 389 forensic laboratories. [33] A 2011 study identified 324 autopsy facilities in the United States, including 272 facilities that reported postmortem exam caseloads, with 12 facilities located within a crime laboratory (see [152] for locations, geographic distribution, and approximate annual caseloads). The 2004 BJS CMEC found that ME/C offices conducted investigations for about one in five of all deaths in 2004. They received referrals in an estimated 956,000 cases and accepted about half — an estimated 487,000 cases. BJS is fielding another ME/C census in 2019 to gather updated information on ME/C staffing, budgets, caseloads, resources, policies, and procedures.

A 2014 study provided more detailed metrics on deaths reported to, certified by, and autopsied by ME/C offices for 28 states based on data assembled using state vital statistics data (see Table 2 in [9]). The percentage of all deaths reported to ME/C offices averaged 35.5% (ranging from 16% to 89% by state). The percentage of deaths reported to and certified by ME/C offices averaged 53% (ranging from 14% to 93% by state). The percentage of cases certified by ME/C offices which also had an autopsy averaged 44% (ranging from 16% to 67% by state). The percentage of all deaths in the state autopsied by ME/C offices averaged 7% (ranging from 4% to 13% by state). The percentage of all deaths certified by ME/C offices averaged 18% (ranging from 9% to 49% by state).

A recent survey conducted by the Drug Enforcement Administration (DEA) National Forensic Laboratory Information System (NFLIS) that received responses from approximately half of ME/C offices in the United States demonstrated the average ME/C work levels in 2016, with levels proportionate to jurisdiction size (see Table 4). [146] This study also found that the average turnaround time to complete a case (defined by completing the death certificate) was 31 days in 2016. Average turnaround times increased with jurisdiction size, with 22 days for small jurisdictions (fewer than 25,000 people), 34 days for medium jurisdictions (25,000 to 249,999 people), and 43 days for large jurisdictions (250,000 or more people). The NFLIS report noted that some states have laws that require ME/C offices to render preliminary manners or causes of death within a certain number of days; toxicological analysis and final determinations may be pending in such cases.

In response to recommendations in the National Research Council's 2009 report *Strengthening Forensic Science in the United States: A Path Forward* (NAS report) [30], the

Table 4: Accepted Cases of Responding Medical Examiners and Coroners, by Type of Injury and Jurisdiction Size

	Total		Large Jurisdiction (250,000 or More)		Medium Jurisdiction (25,000 to 249,999)		Small Jurisdiction (Fewer Than 25,000)	
Type of Inquiry[1]	Average Number Performed	Average Percentage	Average Number Performed	Average Percentage	Average Number Performed	Average Percentage	Average Number Performed	Average Percentage
Death scene investigation	235	84.2	809	63.0	159	96.6	51	80.4
External examination	145	57.5	363	32.0	108	56.3	56	70.4
Review medical records from health care providers	174	54.6	591	50.6	126	58.4	25	52.3
Toxicology analysis	200	45.7	802	59.3	68	44.9	107	42.3
Autopsy performed	163	34.7	711	52.2	47	34.6	33	26.7

[1] Categories for type of inquiry are not mutually exclusive: Percentages will not add to 100 percent.

Source: 2017 NFLIS Medical Examiner/Coroner Office Survey

ME/C community and NIJ supported the establishment of the Scientific Working Group for Medicolegal Death Investigation (SWGMDI), which developed several reports, assessments, and recommendations in 2011-2014 to support the ME/C system infrastructure. [153] NIJ also updated its death investigation guide for scene investigators in 2011. [154] SWGMDI transitioned to the MDI subcommittee under the National Institute of Standards and Technology's Organization of Scientific Area Committees (OSAC) in 2014. [155, 156] There is still great variability in the practice of death investigation across the United States, as jurisdictions struggle to procure and retain needed resources. This variability is particularly apparent in drug-related death investigations, where comprehensive and confirmatory toxicological testing is critical for cause-of-death determinations, particularly because of the opioid crisis and the emergence of new designer drugs. [157]

The overwhelming need identified by the MDI community is the extreme national shortage of practicing board-certified forensic pathologists (BCFPs) who are trained and qualified to perform forensic autopsies, as underscored in the 2009 NAS report. [30, 158] BCFPs are physicians who have not only completed a minimum of four years of medical school and three to four years of medical specialty training in anatomical pathology or anatomical and clinical pathology, but also completed an accredited fellowship year in forensic pathology. Forensic pathology fellowships are critical to the MDI workforce pipeline, as these fellowships provide specialized training in autopsies and death scene investigation under direct supervision by a BCFP. The fellowships also provide general training in courtroom testimony, criminalistics, anthropology, odontology, toxicology, research techniques, and other forensic science-related specialties. After completing the fellowship, newly trained forensic pathologists are then certified by the American Board of Pathology in, at a minimum, anatomical pathology; they must also pass a subspecialty examination to be certified as having special competence in forensic pathology. [10, 30, 32, 159]

This call for increasing the supply of BCFPs was reaffirmed by several recent reports that estimate a current national workforce of only 400-500 physicians who practice forensic

pathology full time, which is less than half of the total estimated need of 1,100-1,200 forensic pathologists for the United States. [7, 10, 18, 160] The true number of BCFPs needed is likely much higher, given that these estimates were developed prior to the rising workloads resulting from the current opioid crisis and the increasing rate of drug-related deaths. Over 70,000 drug overdose deaths were reported in the United States in 2017, according to the Centers for Disease Control and Prevention. [150, 151, 161, 162] The current rate of drug deaths is more than three times the rate reported in 1999. Investigations of suspected drug overdose deaths should adhere to national MDI standards and best practices, including comprehensive toxicological analysis and scene investigations, as well as a complete forensic autopsy. [146, 163, 164]

The number of BCFPs who enter the field each year is not sufficient to achieve appropriate levels of autopsy and keep pace with the attrition of forensic pathologists due to retirement, leaving the field, or death. [10] A 2013 study of the general pathologist workforce forecasted that the total number of practicing pathologists will fall from 18,000 in 2010 to 14,000 by 2030, with retirements peaking in 2021 and continuing to contribute to the decline. [165] The BCFP shortage stems not only from an inability to recruit new forensic pathologists, but also from an inability to retain them in practice, resulting in strong competition among ME/C offices for hiring BCFPs. Approximately 10% of forensic pathologist positions are vacant due to a lack of available, qualified candidates or a lack of funding, indicative of this supply and demand problem. [18] While 76 forensic pathology fellowship positions were approved by the Accreditation Council for Graduate Medical Education (ACGME) across 34 programs, only 39 of these approved fellowship positions (49%) were filled in 2012-2013. [165] The primary reason for this shortage of BCFP candidates is the financial disincentives for physicians to enter the field of forensic pathology. Medical school graduates carry an average student loan debt of $180,000, and average forensic pathology salaries in the public sector are one-half or one-third of the salaries earned by anatomic or clinical pathologists employed in hospitals or private practice settings. [10, 18, 158, 160]

Listening session participants (LSPs) indicated that the shortage of BCFPs is both a recruitment and a retention issue that must be addressed across the entire 10-year progression of medical education required for a forensic pathologist. Increasing students' exposure to — and fostering their interest in — forensic pathology early and often in the education sequence, within the approximately 140 medical schools in the United States as well as within pathology residency programs, can help encourage graduates to choose forensic pathology as a career and alleviate competition between ME/C offices to fill vacancies. [18] LSPs recommended the development of financial incentives, such as student loan repayment or forgiveness programs (see the sidebar, "Maricopa County Medical Examiner Loan Repayment Assistance Program (MELRAP)") and competitive salaries, as the best ways to attract more medical students and pathologists to the MDI field. [166] LSPs noted that several tuition reimbursement programs offered to physicians may be available to recruit for medical specialties or locations in specific need of medical services. [166] At the same time, such programs must be advertised broadly. The development of creative partnerships and affiliations with medical schools to facilitate medical student and pathology resident rotations can attract and sustain the interest of prospective forensic pathologists through quality experiences early in their career trajectories, and can promote research collaborations. [167] A 2017 study based on responses from 54 ACGME-accredited pathology programs indicated that more consistency is needed for forensic pathology training in resident education; the authors provided recommendations for forensic pathology rotations and a core curriculum. [168] Some ME/C offices have developed

Maricopa County Medical Examiner Loan Repayment Assistance Program (MELRAP)

In an effort to address its shortage of forensic pathologists, Maricopa County, Arizona, instituted a loan repayment assistance program to provide an incentive for both current forensic pathology employees and potential recruits. [174] Funded through the county's general fund (from a share of the state sales and property taxes), the plan reimburses participants each quarter-year for loan payments up to $25,000 annually, with a $100,000 maximum benefit. In exchange, participants provide an additional 12 months of service after their last reimbursement, or they are required to repay the county for the last four quarters upon a separation from service. This professional commitment structure allows flexibility by not obligating a long-term commitment in order to receive these benefits, and quarterly reimbursements align with operational budgets and build stability into the workforce. The cost of the program was $25,680 per quarter in FY 2018 (July 2017 to June 2018). The estimated FY 2019 cost is $47,000 per quarter, with 11 eligible forensic pathologists participating in this program. Through the program Maricopa County has been able to fill 16 of its 17 forensic pathology positions and has incentivized its staff to serve the county for several years.

mutually beneficial partnerships with neighboring medical school training programs, and LSPs noted that medical students should also spend time in the field, at death scenes, in addition to working in the autopsy facility. [169-172] The MDI community has also explored using J-1 visa sponsorship and developing workforce exchange programs to recruit and leverage forensic pathology experts residing outside of the United States. [173]

While LSPs indicated that addressing the shortage of BCFPs will require comprehensive, long-term strategies for the entire pathologist pipeline and ME/C system infrastructure, they also noted that there are a number of short-term strategies that can address the forensic pathologist workloads. Increasing the number of MDI personnel and personnel who provide ancillary services may help reduce the BCFP workload strain. For example, specific technical and administrative tasks could be accomplished by medicolegal death investigators based on their specialized knowledge, experience, and task functions. [175] Other qualified personnel, such as autopsy technicians, pathology assistants, transcriptionists, and forensic photographers, can provide specific nonmedical services, and increased staffing and training resources for these positions may have an immediate positive effect on office caseloads. However, LSPs indicated that insufficient staffing budgets prevent many offices from hiring support personnel, and salaries for these positions would need to remain competitive.

While numerous forensic science degree programs are available at the undergraduate and graduate levels, there are only a few formal academic degree programs specifically for medicolegal death investigators, and these programs are only available at the graduate level. [48-52] A 2012 SWGMDI survey found that while educational requirements vary based on the different types of ME/C systems across the country, most ME/C jobs require a minimum of a bachelor's degree, and most MDI instruction is gained through on-the-job training, experience, and certification. [134, 176, 177] While LSPs noted that some MDI-specific training opportunities are available, there are limited resources to support frequent continuing education for death investigators, which can impact both personnel certification as well as office accreditation. Forensic pathologists, as physicians, also have continuing medical education requirements and training considerations to maintain medical licensure and certifications. In some jurisdictions, it takes significant and coordinated efforts to raise the expected level of qualifications for ME/C personnel, particularly for medicolegal death investigators.

The 2009 NAS report and several other groups recommend the certification of MDI personnel. [7, 10, 30, 32, 159, 178] The American Board of Medicolegal Death Investigators (ABMDI) is the only professional certification body for medicolegal death investigators and has operated since 1998 with specific training, experience, and continuing education requirements. [179] A 2014 report indicated that ABMDI had certified 1,200 MDI personnel, and the ABMDI website lists about 2,000 certified MDI personnel currently holding either registry or board certification status as of November 2018. [32] However, this accounts for less than half of the estimated 5,000 to 8,000 medicolegal death investigators in the United States. [178] LSPs noted that the lack of training resources and funding support, particularly for fulfilling continuing education requirements, can be barriers to achieving and maintaining professional certification. [159] Increased access and funding for MDI training and certification can help continue the professionalization of this critical ME/C function.

LSPs indicated that qualified medicolegal death investigators are critical for quality death investigations. LSPs also noted that some agencies have partnered with nearby forensic science academic programs, including anthropology, toxicology, and even mortuary science programs, to offer internships and electives within ME/C offices. These strategic partnerships can leverage the larger supply of forensic science graduates who face strong competition for the limited vacancies available at crime laboratories. These models can promote a robust personnel pipeline to recruit for death investigator and other MDI supporting roles (see the sidebar, "District of Columbia Office of the Chief Medical Examiner").

A 2013 study indicated that the average staffing within offices accredited by the National Association of Medical Examiners (NAME) included five forensic pathologists, four and a half autopsy technicians, and nine investigators. The study also published estimated workload levels that can be useful for state and local jurisdiction self-assessments, including metrics for complete and partial autopsies and correlations between staffing, workloads, and the populations served. [145] While this study and the BJS and NFLIS surveys provide average workload estimates, SWGMDI made recommendations for staffing levels based on the number of autopsies performed annually, though metrics fluctuate based on the number of MDI services provided, jurisdictional size, and organizational structure. [11, 12, 145, 146] Increased MDI staffing by qualified medicolegal death investigators in particular can inform ME/C decision-making by gathering critical information to present to and/or discuss with the BCFP, especially when determining case acceptance and autopsy decisions at the beginning of an investigation. LSPs noted that nurse death investigators who possess a foundational medical skill set can also fill these types of support positions, and the International Association of Forensic Nurses (IAFN) even published forensic nurse death investigator education guidelines. [180, 181] While Project FORESIGHT only has limited information related to casework, personnel, and expenditures for forensic pathology, assessments of workloads, resource allocations, efficiencies, and the return on investment of MDI services could be enhanced if more ME/C offices participated in and reported to Project FORESIGHT. [37, 182]

The dire shortage of forensic pathologists also threatens the accreditation status of many ME/C offices by increasing individual workloads. Based on their accreditation standards, NAME and the International Association of Coroners and Medical Examiners (IACME) recommend an autopsy caseload of no more than 250 autopsies per year for each forensic pathologist. [183, 184] Performing over 250 autopsies is considered a Phase I violation for

accreditation. If a pathologist performs over 325 autopsies per year, this is deemed a Phase II violation — that is, a deficiency that "may seriously impact the work or adversely affect the health and safety of the public or agency." An agency will lose full accreditation status for any Phase II violation. [146] Furthermore, it is a Phase I violation if 90% of reports on postmortem examinations are not completed within 60 calendar days from the time of autopsy, and a Phase II violation if a report is not completed within 90 days from the time of autopsy. Additionally, under NAME's accreditation standards, ME/C offices face a Phase I violation if 90% of autopsies and external examinations are not performed within 48 hours and a Phase II violation if their autopsies and external examinations are not performed within 72 hours. [185] These limits may impact ME/C offices' decisions on the number of cases accepted, the number of autopsies performed, and the level of effort for the entire death investigation process. Based on a U.S. population of 320 million, a 2015 study projected that 1,280 forensic pathologists are needed in order to maintain a caseload that does not exceed 250 autopsies per year per pathologist, and another study determined that only four of 24 states with a state medical examiner system had a sufficient number of forensic pathologists in 2013 to remain at or below this autopsy threshold. [18, 186]

As discussed in the Accreditation and Quality Management section of this report, accreditation demonstrates compliance with industry and professional standards and performance criteria. [187] NAME and IACME both publish professional standards related to the performance of autopsies and medicolegal death investigations as well as the incorporation of other forensic ancillary services (e.g., toxicology, histology, radiology). Both organizations provide accreditation through scheduled independent reviews and inspection processes, in accordance with accreditation requirements and checklists available online. [183, 184, 188] These standards also require that the majority of an ME/C office's death investigators with five or more years of experience be certified by ABMDI, or the office faces a Phase I violation. Additionally, under IACME standards the investigative scene reports and photographs should be available to the forensic pathologist before autopsy, and the circumstances of death should be reviewed prior to autopsy. Some ME/C offices have also pursued accreditation to the ISO 17020 standard, the international standard for inspection bodies, which was one of the first standards approved for the OSAC Registry in 2017. [185, 189, 190] LSPs noted that ME/C offices need greater awareness to become familiar with this standard and to determine its application for MDI services, which may require additional resources. [190] While approximately nine in 10 publicly funded crime laboratories in the United States are accredited, only about 100 of the estimated 2,400 ME/C offices have achieved accreditation. [187]

Although overall participation in accreditation programs has been limited, participation is growing. As of 2013, approximately 60 ME/C offices were accredited by NAME, and these offices serviced approximately 30% of the U.S. population. The number of NAME-accredited offices has grown significantly within a short time. By 2016, 82 ME/C offices in 41 states were accredited by NAME, covering approximately 130 million people, or 40% of the U.S. population, and 21 ME/C offices in 12 states were accredited by IACME. [7, 8, 145] As of November 2018, 86 ME/C offices are accredited by NAME and 24 ME/C offices are accredited by IACME. [183, 184] While this upward trend is promising, additional resources are needed to encourage further ME/C office accreditation, advance the quality of MDI services, and increase public trust in these services.

NAME recommendations for the investigation, diagnosis, and certification of deaths related to opioids call for a complete autopsy, complete scene investigation, and comprehensive toxicological analysis to accurately interpret the findings and support the cause and manner

of death determinations. [163] Due to increasing workloads attributed to the opioid crisis and low budgets, particularly for smaller offices, ME/Cs could be forced to conduct limited examinations in order to avoid surpassing autopsy thresholds. Offices may resort to using external examinations, partial autopsies, or toxicology analysis alone in some cases, as a substitute to conducting a complete forensic autopsy. A 2014 study that examined the ME/C work performed among 28 states found that ME/C certified cases that also included an autopsy varied widely, between 21% and 73%, and that several states with low autopsy rates also reported relatively large numbers of external exams and/or partial autopsies. [8]

For these reasons, understanding the nature of MDI workload and backlogs is challenging, as casework may be better understood through the lens of ME/C case acceptance policies and death investigation decision-making. Increasing caseloads and profoundly inadequate budgets can force ME/C offices to make difficult decisions when determining which decedents will receive autopsy or toxicology testing, particularly in smaller ME/C offices that manage limited annual budget allocations. Variability in MDI capabilities and services can result in the inequitable application of death investigations, which may have deleterious effects on the fair administration of justice. LSPs noted that the quality of death investigations correlates directly with budgets. Resource shortfalls may contribute to an underestimation of the number of drug-related deaths. Some cases may not even be referred to ME/C offices due to a perceived or known shortage of resources. LSPs also noted that some jurisdictions still view medicolegal death investigation as an optional service, unlike more available medical services such as trauma care and cancer treatments. There can also be large discrepancies in the provision of services in rural communities. MDI personnel who are located at smaller offices or who operate in a part-time capacity (though they are still required to respond anytime, day or night) may not even be aware of the national discussions around strengthening the ME/C system and may lack the tools, infrastructure, and pathways to implement MDI best practices. LSPs indicated that personal interactions with these offices are necessary to bridge knowledge and communication gaps.

LSPs also indicated that the regionalization of MDI services may help consolidate expertise and provide shared resources and instrumentation, allowing access to costly technologies that might not otherwise be available. SWGMDI offered several considerations and detailed metrics for the construction and staffing of regional autopsy and MDI centers, as well as the costs to establish and maintain them. [190, 191] Regionalization can provide higher levels of service to smaller or rural communities with ME/C offices that only handle a few cases per year. SWGMDI documented the workplace locations of BCFPs in the United States, identifying possibly underserved areas where regional ME/C centers may improve access to MDI services. [192] Regionalization can also provide mentorship opportunities to enhance training and continuing education efforts. Consolidated facilities may lead to a collegial professional environment, more attractive jobs, and reasonable caseloads, as demonstrated by many centralized state systems. Regionalization may also allow MDI service providers to identify and respond with agility to emerging public health and safety threats and facilitate the building of a research culture. In the aforementioned 2013 NAME study, researchers noted that the average facility size for NAME-accredited offices was almost 30,000 square feet, with sizes ranging from 1,500 to 136,000 square feet. [145] Regionalization efforts should consider unique facility and equipment needs for their service area, since the 2012 NAME survey of state medical examiner offices found that facility needs and areas in need of improvement were fairly diverse. [193] In addition to regionalization, co-locating MDI services with forensic science laboratories may optimize the provision of those forensic services. Co-locating forensic services such as drug chemistry, antemortem and postmortem

toxicology, and MDI services can enhance a jurisdiction's public safety and public health responses to drug threats. Consolidation of these services can be accomplished through sharing agreements or memoranda of understanding, and can motivate innovative collaborations and coordination between forensic service providers.

The provision of additional equipment may also have a tremendous impact on workload when applied strategically to key MDI practices. LSPs noted that fingerprint scanners and database interfaces facilitate significantly faster decedent identifications and next of kin notifications, compared to the processes and time required for visual identifications. This approach is particularly important for handling mass disasters and other critical incidents. However, resubmissions to fingerprint databases in cases with no initial matches may cause increased workloads. Advanced imaging and radiography technologies, such as computed tomography (CT) scanners, can supplement and in some cases even supplant medical autopsies, increase workload efficiencies, and/or serve as a pre-autopsy triage. [194-196] Although it can be costly to install and maintain CT scanners and train personnel in their use, the costs may be outweighed by the benefits; the technology's 3D visualizations can serve as "virtual autopsies" to support ME/C determinations, assist the courts by providing a better understanding and visualization of injuries, and provide an option to accommodate personal, religious, or cultural sensitivities to autopsy. By maximizing the impact of these technologies through the regionalization of services, ME/C offices can generate cost savings through economies of scale, and costs can be offset by partnering with radiology units and medical schools. [197, 198]

LSPs noted that ME/C offices generally do not have the resources necessary to successfully apply for federal grant programs and that an "MDI center" model could help streamline grant applications for targeted objectives and small purchases. Formula grant programs based on national vital statistics could advance MDI services using a statistical approach. Some ME/C offices that need the most support possess the least experience in writing grants and must learn how to justify their business case, often by obtaining essential feedback through several cycles of unsuccessful applications. While a few recent federal programs have provided support for targeted MDI activities, such as addressing the opioid crisis and sudden infant/child death, there is still no principal federal entity or dedicated and consistent federal funding program charged with strengthening MDI services in the United States. [199-201] However, there are over 40 federal agency programs that rely on the data generated by the MDI system to further their missions and support federal programs, policies, and rule-making decisions. [7]

The NIJ Coverdell Forensic Science Improvement Grants program provides some funding for MDI purposes, and the program permits expenses related to personnel, equipment, supplies, IT systems, facilities, accreditation, education, training, and certification. However, as noted in the 2009 NAS report, the Coverdell program is not strictly dedicated to the MDI system. Rather, the Coverdell program's formula and competitive components provide funding to improve the quality and timeliness of all forensic science services. ME/C offices compete with crime laboratories for this limited funding, and the latter generally have better internal grant application and management resources. [32, 96] In 2017, NIJ initiated the Strengthening the Medical Examiner-Coroner System program, a dedicated funding mechanism for supporting forensic pathology fellowships and providing the resources necessary to achieve accreditation. [166] In its first two years, this program has awarded $4.8 million for 13 awards to support ME/C accreditation and 16 forensic pathology fellowships, addressing some of the specific recommendations cited by the 2009 NAS report

and recent MDI working groups. [202, 203] However, no dedicated federal appropriations have been established specifically for MDI purposes.

MDI research remains a critical need, not only to help understand deaths that remain unexplained following autopsy and comprehensive investigation, but also to identify the most effective provision of MDI services and build a knowledge base beyond the individual case level that could greatly enhance federal programs. [7, 204] LSPs indicated that fostering a research culture in the MDI system remains a challenge, not only due to the shortage of MDI personnel and increasing caseloads, but also because of ME/C system disparities and because most ME/C offices operate apart from academic institutions that regularly compete for forensic science research funding and maintain dedicated grant support offices. MDI research is complicated by the scarcity of funding sources for death investigations and forensic pathology, compared to the research support available in other medical fields. A review of publications from 1985 to 2010 authored by BCFPs estimated that only 12% of authors received some form of research funding support, and two-thirds of publications consisted of case reports or case series. [205] LSPs echoed the findings of this review and noted that ME/C offices need better access to grant-writing resources and research personnel in order to develop well-designed, high-impact projects that are competitive for federal research funding. While grant opportunities for new investigators are helpful, LSPs noted that research funding opportunities that promote career development or mentorship roles may incentivize the growth of a research infrastructure in the field of death investigation. LSPs noted that many ME/C offices have an abundance of research ideas and data but lack the personnel, time, and resources to implement research projects. Even offices associated with academic institutions face this challenge due to personnel service requirements. [205, 206] NIJ recently established the Research and Evaluation in Publicly Funded Forensic Laboratories program, which encourages applicant laboratories to consider funding a postgraduate (master's or doctorate) fellowship as part of their proposal. [207] ME/C offices can also post research ideas and office contact information to the NIJ webpage for Connecting Postgraduate Researchers with Publicly Funded Forensic Laboratories, to identify researchers who can assist with preparing an application for forthcoming NIJ research solicitations. [42]

LSPs noted the need to develop collaborations, regular communications, and formal and informal relationships with public safety and public health partners to help support mutual goals and needs. Formal coordination at jurisdictional or regional levels can help ME/C offices provide systems-based approaches that increase the recognition of the impact of ME/C services and address mutual criminal justice system and community challenges. LSPs indicated that some ME/C jurisdictions recognized that they had not been collecting the appropriate data in order to communicate their needs and make their business case to state and local policy and budget decision-makers. This awareness resulted in a statewide survey to determine gaps and specific needs, and the development of more localized data-driven approaches. Some LSPs noted that the development of a state oversight board for MDI activities has helped provide critical input and generate state and local support for MDI services. By meeting regularly and ensuring representation from major stakeholders, such oversight boards can facilitate connectivity among senior-level government and agency leaders as well as MDI staff to promote a shared sense of direction. Legal practitioners should also be aware of the challenges associated with court appearances on the MDI workload, particularly when courts require testimony — with little notice or compensation — from a specific forensic pathologist who has moved to a different ME/C office, rather than accepting testimony from the servicing ME/C office. [208] Given the

shortage of BCFPs, the MDI community has noted that these court requirements can cause significant stress and may be a disincentive for BCFPs to remain in the field.

LSPs noted that regular cross-training between law enforcement agencies and ME/C offices promotes awareness of each other's resources and capabilities, and contributes to information-sharing efforts that support accurate cause and manner of death determinations. These collaborations are particularly important at the very beginning of a death scene response, when the processing of both the death scene and potential crime scene are intertwined. Law enforcement often provides the initial on-site assessments and decides whether or not to engage the ME/C office. LSPs noted that several jurisdictions have organized regular meetings between partnering agencies and established fatality review teams composed of multiple stakeholders (e.g., law enforcement, public health, corrections, social workers, attorneys) to provide more comprehensive death investigations. These review teams routinely examine infant and child deaths, elder deaths, drug overdose deaths, and domestic violence fatalities, and review teams are mandated by state or local legislation in some cases. [201, 209-212]

LSPs noted that New York City's RxStat program serves as a model for facilitating collaborations among multiple stakeholders to address the drug and opioid crisis. [213] Some ME/C offices have even hired a full-time, dedicated forensic epidemiologist who can conduct research, surveillance, and data analysis and identify public health and public safety issues and trends, such as demographic or geographic drug overdose clusters. [214-217] ME/C offices have a wealth of untapped data with high granularity that are not included on the death certificate. This information can be invaluable for death and injury prevention by developing actionable intelligence to shape public health and safety and public health policy and practice. Considering the ubiquity of digital devices (e.g., audio/video recording systems, wearable devices, medical devices), the MDI community should also consider collaborations with digital forensics examiners to identify ways to develop actionable intelligence from digital and multimedia evidence that can help death investigators understand the circumstances surrounding a death. (See the Digital and Multimedia Evidence section for further information.)

ME/C offices maintain a wealth of data that can inform public safety and public health operations. At the same time, public health and public safety agencies also have critical data that can enhance ME/C operations. While ME/C offices provide valuable information and data used for criminal justice purposes at the federal, state, and local levels, many ME/C offices are situated within public health departments, and most ME/C offices do not have direct access to law enforcement systems that would facilitate death investigations. For example, LSPs indicated that ME/C offices typically cannot obtain an Originating Agency Identifier Number (ORI) that would allow them to have better access to law enforcement databases, specifically fingerprint databases to help identify decedents. Some ME/C offices have developed formal arrangements with their local law enforcement agencies to facilitate searches in the Automated Fingerprint Identification System. LSPs also indicated that ME/C offices need direct access to prescription drug monitoring programs (PDMPs) to facilitate timely death investigations for suspected drug overdoses. [218] See the sidebar, "Prescription Drug Monitoring Programs," for more information.

LSPs also indicated that ME/C offices still need a robust system-wide infrastructure to enable data and information sharing among ME/C offices and data interoperability to inform external public health and safety and public health stakeholders. [7, 219, 220] The

Prescription Drug Monitoring Programs

Medical examiner and coroner (ME/C) offices need to have direct access to prescription drug monitoring programs (PDMPs) to facilitate timely death investigations for suspected drug overdoses. [219] The National Institute of Justice and the Bureau of Justice Assistance (BJA) co-hosted a roundtable meeting in August 2018 with several representatives from state PDMPs, their ME/C counterparts, and the BJA PDMP Training and Technical Assistance Center (PDMP TTAC) to identify current best practices for data sharing to support drug death investigations. [220] Participants provided updates on their existing partnerships and identified strategies to advance communications and collaborations for addressing shared public health and public safety goals. Participants also discussed mechanisms for overcoming technical barriers to data exchange, including recent state legislative actions that enable direct and timely ME/C access to data. The meeting proceedings were used to develop a best practices report titled "Prescription Drug Monitoring Program and Medical Examiner/Coroner Meeting: Building Collaboration" to support and promote PDMP and ME/C data access and information-sharing activities.

DEA NFLIS survey inquired about ME/C use of information management systems and found that in 2016, approximately 32% of ME/C offices reported having a computerized, networked information management system; 31% reported having a manual record keeping system; 30% reported having a partially computerized system with some manual record keeping; and almost 7% reported using a computerized, nonnetworked system. [146] The percentage of ME/C offices with computerized networks increased with servicing jurisdiction size: 13% of ME/C offices in small jurisdictions, 32% in medium jurisdictions, and 74% in large jurisdictions had computerized networks. In contrast, approximately 90% of forensic laboratories used a computerized laboratory information management system (LIMS) in 2014. [62] (See the Workload Landscape section of this report for further discussion on LIMS). While several ME/C respondents indicated plans to install or upgrade these systems, all ME/C offices and all local, state, regional, and federal stakeholders stand to benefit greatly from increased coordination and wider implementation of networked case and information management systems. (See the Information Technology section in this report). For example, ME/C data could be combined with datasets from forensic science laboratories to identify trends in seized drugs, toxicology, and suspected drug overdose death investigations. Recent recommendations to enhance the MDI data infrastructure, quality, and accessibility include establishing essential MDI data elements and data element specifications to facilitate timely data sharing and statistical reporting and promoting interoperability among current electronic systems used within the MDI community, including electronic death registration systems. [7, 157]

LSPs also noted the importance of NamUs to support investigations (see the sidebar, "National Missing and Unidentified Persons System (NamUs)"). [109] Each year, approximately 600,000 individuals go missing and 4,400 unidentified deceased persons are discovered; 1,000 of these cases remain unsolved after one year, as demonstrated in the BJS ME/C census. [12] NamUs was established by NIJ in 2007 and offers law enforcement agencies, ME/C offices, family members, and victim advocates a powerful tool for resolving these cases. A few states have recently mandated that their ME/C offices and law enforcement agencies use NamUs for missing persons and death investigations, and some jurisdictions host a "Missing Persons Day" to encourage connections that may resolve these cases. [221]

MDI personnel also encounter workplace stressors and experience vicarious trauma — as described in this report's earlier section on Health and Wellness — not only through their daily activities, but also when managing critical incidents. LSPs noted that ME/C

National Missing and Unidentified Persons System (NamUs)

Funded by the National Institute of Justice (NIJ) and managed in partnership with the University of North Texas Health Science Center's Center for Human Identification (UNTCHI) under NIJ award number 2016-MU-BX-K007, the National Missing and Unidentified Persons System (NamUs) brings together law enforcement, medical examiners, coroners, forensic experts, families, and the public to help resolve missing and unidentified person cases throughout the nation. NamUs provides criminal justice users a secure, online system to store, share, and compare sensitive case information, and a public component gives family members and other public stakeholders a mechanism to report cases and participate in the search for potential matches. The NamUs database currently contains:

- 16,289 published missing person cases
- 12,855 published unidentified person cases
- 5,920 cases of unclaimed decedents who have been identified by name, but whose next of kin have not been located for death notification

As a national resource center for missing and unidentified persons cases, NamUs provides forensic services to assist with case resolutions — including forensic odontology and fingerprint examination — and leverages DNA analysis and anthropological services performed by subject matter experts within the UNTCHI forensic laboratories. A team of Regional System Administrators (RSAs) serves as a force multiplier for criminal justice agencies across the country, providing investigative support and guidance to assist with case investigations. RSAs also directly support families of missing persons by connecting them to investigating agencies to file missing person reports, facilitating DNA collections, and participating in missing person events across the country to intake new cases and augment existing NamUs case files.

By connecting people, information, forensic science, and technology, NamUs supports families and provides medical examiners, coroners, and criminal justice professionals with access to the investigative and scientific tools needed to find missing persons, identify decedents and victims of crime, resolve criminal cases, and reduce violent crime and human trafficking.

Of the 3,607 decedent cases that have been resolved in NamUs to date, 442 specifically indicate that the manner of death was homicide. However, there are additional categories which could also involve victims who have died as a result of violent crime, including 293 cases noted to have a "pending" manner of death, 879 cases noted to have an "undetermined" manner of death, and 664 cases with no manner of death noted in the database. An in-depth review of these cases would reveal many cases of homicide. For instance, cause of death may be reported as a gunshot wound, strangulation, or blunt force trauma, despite the fact that the manner of death is noted as "undetermined."

NamUs has been recognized around the world not only for its ability to match missing and unidentified decedents, but also for giving members of the general public the ability to participate in adding cases to the NamUs missing persons database. In 2011, NamUs received the Samuel J. Heyman Service to America Medal from the Partnership for Public Service.

personnel work directly with grieving families in performing next of kin notifications and regularly manage intense situations that can be mentally and emotionally draining. The MDI community has also been particularly affected by the opioid crisis and the resulting influx of deaths requiring complete autopsy, causing MDI workforce stress and burnout. The resources discussed in the Health and Wellness section of this report can also be applied to the needs of the MDI community. SWGMDI provided specific recommendations for critical stress management and ways to promote MDI workforce resiliency for both mass fatality incidents and normal office duties, including debriefings and access to counseling professionals or peer counselors. [70] The U.S. Department of Justice (DOJ) Office for Victims of Crime also recently developed a mass violence toolkit to enhance response and recovery efforts for critical incidents. [222]

While the ME/C community has contributed enormously in recent years to national discussions on strengthening the forensic sciences, MDI services are performed almost entirely at the state and local levels across the United States, and no single federal agency is charged with strengthening the ME/C system. [7, 10, 155, 156] In 2018, the DOJ Office of Justice Programs and the Department of Health and Human Services established a new Federal Interagency Working Group on Medicolegal Death Investigation (MDI-WG) to coordinate federal activities to strengthen the U.S. ME/C system. The MDI-WG is identifying both short- and long-term strategies to develop and implement federal programmatic activities that support national initiatives and strategies for public health and public safety. The MDI-WG is considering several activities including:

- Developing technologies and systems to facilitate information sharing and data sharing between ME/C offices; toxicology laboratories; and federal, state, and local entities, with a specific focus on combating the opioid crisis
- Addressing the shortage of forensic pathologists
- Coordinating MDI research priorities
- Strengthening drug death investigations
- Strengthening mechanisms for reporting data from drug deaths
- Supporting postmortem toxicology screening and analysis, particularly for novel synthetic drugs

VIII. Special Topics

During the information gathering and research phase of this assessment, several significant areas of special focus developed. These are areas or topics requiring additional focus and attention due to prevalence, increased needs, and innovative promising practices.

A. Opioid Crisis and Emerging Drug Threats

Needs:

- Sufficient and consistent funding and strategic planning for resources and equipment to address the soaring growth in U.S. forensic laboratory expenditures associated with the opioid crisis, estimated to be $270 million in 2015 based on analysis of representative forensic laboratories that participate in Project FORESIGHT and forensic laboratories responding to the 2014 Census of Publicly Funded Forensic Crime Laboratories. Compared to typical laboratory growth in expenditures of less than 3% per year for the past decade, the costs to address the opioid crisis include a 37% increase in expenditures for the analysis of drugs/controlled substances and a 25% increase for toxicology analysis (includes antemortem and postmortem toxicology).
- Sufficient, consistent funding and strategic planning for the equipment and resources needed to increase efficiencies in forensic laboratories and medical examiner/coroner (ME/C) offices and address the technical challenges of analyzing synthetic analogues. Between 2011 and 2017, there were substantial increases in turnaround times and backlogs at forensic laboratories. Based on Project FORESIGHT data, the average turnaround time for drug/controlled substance casework grew from 58 days to 79 days (36% increase), and the average 30-day backlog soared from 385 to 1,250 cases (225% increase). For toxicology analysis (excluding blood alcohol analysis), average turnaround times grew from 38 days to 65 days (73% increase) and the average 30-day backlog increased from 325 cases to 470 cases (45% increase). For postmortem toxicology analysis, the turnaround times increased from 36 days to 53 days (46% increase).
- Access to certified reference materials to accurately identify fentanyl analogues and other novel psychoactive substances in both drug and toxicology evidence.
- Strengthened coordination among forensic laboratories and medical examiner/coroner offices and other public safety and public health stakeholders to advance information and data sharing efforts.

- Resources and laboratory instrumentation to implement standardized toxicology analysis and death investigations to advance data interpretation and reporting.
- Resources to help forensic laboratories coordinate with public safety and public health officials to implement field detection equipment for developing actionable information and sharing timely data.

Challenges:

- Forensic laboratory analysis and screening for both drug and toxicology (antemortem and postmortem) is complicated by the continuous emergence of new drugs and drug mixtures, requiring research and implementation of new laboratory methods and testing protocols and advanced technologies and equipment.
- Costs of increasing forensic workloads to address opioid-related casework may result in resources being diverted from other forensic disciplines to the detriment of other forensic analysis.
- Funding levels are not commensurate with laboratory workload increases.
- While some regions are affected by the opioid crisis and emergence of fentanyl and related analogues, other regions face increasing trends for other controlled substances including methamphetamine, cocaine, and other stimulants.
- Handling unknown and potentially hazardous substances presents safety concerns for forensic science personnel, particularly for crime scene and death investigation teams, but also laboratory personnel.
- Legalization and decriminalization of marijuana and permitted production of hemp may present new challenges for forensic laboratories by influencing the number and types of cases received and requiring implementation of new testing strategies.
- Testing methods must be developed to test THC (tetrahydrocannabinol) from a wide variety of plant-based materials, edibles, and extracts and toxicology samples from driving while impaired (DWI) cases.

Promising Practices:

- Increased forensic laboratory and ME/C collaborations with public safety and public health stakeholders, such as overdose fatality review teams, to support information and data sharing.
- Deploying field-portable drug detection instrumentation to provide preliminary results and triage casework, in coordination with a forensic laboratory for operational management and oversight.

The opioid crisis has been specifically implicated in the dramatic rise in drug overdose deaths in the United States. There were 70,237 overdose deaths in 2017, approximately three times the rate of drug overdose deaths reported in 1999. [150, 151, 223] Due to the opioid crisis and the emergence of fentanyl and other drug threats from novel psychoactive substances (NPS), forensic laboratories have seen tremendous increases in workloads, and autopsy totals are threatening the accreditation status of ME/C offices. The chemical structures of NPS are similar to those of known controlled substances, and NPS are being designed to stay ahead of federal and international laws that restrict the distribution and sale of specific chemicals. [149] At the same time, the emergence of other drug threats,

such as synthetic cannabinoids, synthetic cathinones ("bath salts"), and stimulants such as methamphetamine and cocaine, continues to affect communities as demonstrated by regional drug trends and mortality rates. [224] The Centers for Disease Control and Prevention (CDC) reported that deaths involving psychostimulants with abuse potential, which include drugs such as methamphetamine, increased from 5% of all drug overdose deaths in 2010 to 11% in 2015, and rates of overdose deaths involving cocaine and psychostimulants increased by 52.4% and 33.3%, respectively, from 2015 to 2016. [150, 151, 225]

Methamphetamine, cannabis/THC, cocaine, and heroin continue to be the most frequently identified drugs, together representing 68% of all drugs reported by U.S. forensic laboratories in 2017 to the Drug Enforcement Administration (DEA) Diversion Control Division's National Forensic Laboratory Information System (NFLIS). Fentanyl emerged dramatically in 2014, with frequency varying by region; the Northeast and Midwest regions faced the most drastic upward trends in fentanyl reports. [226-228] Forensic analysis has become more challenging due to the rise in fentanyl, fentanyl analogues, and other NPS. According to NFLIS data, only two synthetic cannabinoids and five synthetic cathinones were reported in 2009. By 2015, 84 different synthetic cannabinoids and 35 different synthetic cathinones were reported. [229] NFLIS data demonstrate a significant increase in the number and diversity of new and emerging fentanyl-related substances observed in forensic casework between 2015 and 2016 alone. [230] Each newly identified substance requires additional research, development and implementation of laboratory methods, testing protocols, and advanced technologies and equipment to ensure sufficient sensitivity and specificity to detect these emerging drugs in forensic casework.

A recent report published by the Association of State and Territorial Health Officials (ASTHO) also noted that increased education and awareness are needed to standardize the analysis and reporting of these substances in drug death investigations. The ASTHO report emphasized that death certificates need specific details of the drugs involved in the death to ensure the completeness and accuracy of drug death statistics and to avoid undercounting. [208] The CDC notes that "at autopsy, the substances tested for and the circumstances under which the toxicology tests are performed vary by jurisdiction. This variability is more likely to affect substance-specific death rates than the overall drug overdose death rate. The percentage of drug overdose deaths for which at least one specific drug was identified as being involved varied by year, ranging from 75% to 79% from 1999 through 2013 and from 81% to 88% from 2014 through 2017." [161] A recent study estimated that 70,000 unintentional, opioid-related overdose deaths from 1999 through 2015 may have been missed because of incomplete reporting. [209] The President's Commission on Combating Drug Addiction and the Opioid Crisis recommended that "the Federal Government work with the states to develop and implement standardized rigorous drug testing procedures, forensic methods, and use of appropriate toxicology instrumentation in the investigation of drug-related deaths. We do not have sufficiently accurate and systematic data from medical examiners around the country to determine overdose deaths, both in their cause and the actual number of deaths." [149] Listening session participants (LSPs) noted that additional resources and laboratory instrumentation are needed to implement standardized toxicology analysis and death investigations and to advance data interpretation and reporting. In order to promote timely access to critical data, some ME/C offices issue preliminary death certificates (pending toxicology) and finalize them once further information becomes available. While presumptive testing is extremely valuable, mechanisms for issuing preliminary findings may be impacted by accreditation requirements. [210]

1. Increases in Workload and Costs to Forensic Laboratories

Congress has specifically recognized the alarming proliferation of heroin and synthetic drugs like fentanyl that have had a crushing effect on crime laboratories and understood that synthetic drugs in particular take longer to analyze than traditional drugs and chemicals, all of which results in a significant increase in case backlogs. [231] Congress has also recognized that the ME/C system has been overwhelmed with the volume of autopsies resulting from overdose deaths related to heroin and synthetic drugs. The FY 2018 federal appropriations for the Paul Coverdell National Forensic Science Improvement Grant program, administered by the National Institute of Justice (NIJ), included an additional $17 million specifically to target the challenges the opioid epidemic has brought to the forensics community. The FY 2018 appropriation of $30 million for the Coverdell program provided funding to improve the quality and timeliness of all forensic science services. [96, 231] However, forensic laboratories and ME/C offices continue to struggle to keep up with the workloads, increasing costs, and cumulative effects associated with the opioid crisis.

A report from the Council of Economic Advisors (CEA) suggests that accounting for indirect costs not previously considered increases the estimate of the annual cost of the crisis by nearly 600%, to a staggering $504 billion. [232, 233] Those additional societal costs reflect the loss in human life from overdoses beyond the previously considered increases in health care costs, substance abuse treatments, and the costs to the criminal justice system. Not considered in the CEA estimate are the indirect costs borne by crime laboratories, and ultimately to society, as laboratory resources are diverted to opioids and away from other forensic disciplines. A study, supported in part by the NIJ Forensic Technology Center of Excellence (FTCoE), was conducted to determine forensic laboratory costs associated with the opioid crisis. The study examined drug/controlled substance and toxicology workloads and costs based on an analysis of the data from representative forensic laboratories that participate in Project FORESIGHT. [185, 234] The study attempted to identify the magnitude of this problem, while detailing the direct costs and the opportunity costs that impact other forensic disciplines as resources are diverted to the opioid crisis. The intent of the study was to provide policymakers with a broader view of the societal costs as decisions are made to battle this crisis.

Table 5 offers a single-year snapshot of the magnitude of the opioid problem, with an estimated national cost to forensic laboratories of $270 million in 2015. Even more startling is the pace of the growth in expenditures for the analysis of drugs/controlled substances and toxicology. Based on data from the representative laboratories in the Project FORESIGHT database, the growth rate of a typical laboratory's total budget has been under 3% per year for the past decade, as measured by the median budget growth. [37] For the two areas of investigation directly related to opioids — drugs/controlled substances and toxicology — the growth in expenditures from FY 2015-2016 to FY 2016-2017 was dramatic: a 37% increase in expenditures for drugs/controlled substances and a 25% increase in expenditures for toxicology (including both antemortem and postmortem toxicology), far outpacing the growth in total laboratory expenditures. The result is a substitution effect, as resources are diverted from elsewhere in the laboratory to address casework in these areas. A FORESIGHT assessment of capital investments compared to personnel expenses indicates a shifting of resources as, for example, toxicology units

Table 5: Estimated Opioid-Related Crime Laboratory Expenditures in 2015[11]

	Drugs/Controlled Substances	Toxicology	Other Areas of Investigation	Total Opioid Expenditures
FORESIGHT Laboratories	$25,276,113	$28,096,584	$39,839,340	$93,212,037
Non-FORESIGHT BJS Census Laboratories	$38,829,971	$43,162,867	$61,202,464	$143,195,302
Other Laboratories	$9,185,486	$10,210,461	$14,477,847	$33,873,794
NATIONAL TOTAL COSTS	$73,291,570	$81,469,912	$115,519,651	**$270,281,133**

have shifted budgets towards more sensitive equipment for the detection of synthetic drugs. There have been dramatic increases in both turnaround times and backlogs, as well. Between 2011 and 2017, the average turnaround time for drug/controlled substance casework grew from 58 days to 79 days (36% increase), and the average 30-day backlog soared from 385 to 1,250 cases (225% increase). For toxicology analysis (excluding blood alcohol analysis), average turnaround times grew from 38 days in 2011 to 65 days in 2017 (73% increase), and the average 30-day backlog increased from 325 cases to 470 cases (45% increase) during this same timeframe. For forensic laboratories in the FORESIGHT database that performed postmortem toxicology analysis, the turnaround times increased from 36 days in 2011 to 53 days in 2017 (46% increase).

2. Equipment and Reference Materials

In addition to traditional analytical instrumentation for seized drug and toxicology analysis, laboratories may also need to incorporate several new types of sophisticated instrumentation to fully characterize the new and emerging synthetic drugs. Some screening strategies may be used to determine drug class characteristics, develop actionable information, and guide analysis protocol decisions. However, some screening tests may not be specific enough to detect all significant or emerging drug threats or may have cross-reactivity. Comprehensive characterization and expert interpretation are especially critical for the analysis of NPS, drug mixtures, and poly-drug toxicology samples, particularly if the substances are present at low concentrations. In order to investigate and prosecute controlled substance analogue cases, the structural characterization of drugs or metabolites is essential to demonstrate that the substance is both substantially similar in chemical structure to a controlled substance, and has a substantially similar pharmacological effect (e.g., stimulant, depressant, hallucinogenic) on the central nervous system. [238] However, laboratories may not have all of the instrumentation, facilities, and infrastructure necessary to conduct every level of analysis. Fortunately, forensic laboratories and the drug and toxicology community, including the American Society of Crime Laboratory Directors (ASCLD), have identified several types of instrumentation and techniques that can address

[11] To arrive at the jurisdictional costs, the efficient frontier costs for the corresponding caseload during the same period analyzed in the CEA report were calculated first for Project FORESIGHT forensic laboratories and then non-FORESIGHT laboratories from the Bureau of Justice Statistics (BJS) Census of Publicly Funded Forensic Crime Laboratories. This analysis represents a minimum cost for the given caseload, not only for drugs/controlled substances and toxicology, but also for other forensic disciplines. The caseload for the remaining laboratories was estimated based on data in the BJS Census and the relationship between caseloads, population, and the crime rate for each area of investigation. National estimates represent the sum of the jurisdictional estimates.

these analytical challenges and advance the detection and identification of new chemical structures. [236, 237] The forensic science community is also facilitating access to additional analytical datasets, developing new communication pathways, and sharing information on newly discovered substances to support structural elucidations and reduce the duplication of efforts, through the work of the Scientific Working Group for the Analysis of Seized Drugs (SWGDRUG), the National Institute of Standards and Technology (NIST) NPS Data Hub, and the DEA Synthetic Opioids Real-Time Communication Network (see the sidebar, "The Drug Enforcement Administration's Synthetic Opioids Real-Time Communication Network"). NIJ's FTCoE also developed a series of webinars to help forensic practitioners understand and address the challenges of the opioid crisis (see the sidebars, "FTCoE Best Practices Guidance for Advancing Research Initiatives and Combatting the Synthetic Drug Epidemic Webinar Workshop Series" and "FTCoE Webinar Series: Opioid Crisis — A Public Health Enemy," for additional information). [157, 238-241] Laboratories must consider their own instrumentation needs based on an instrument's analytical capabilities — including sensitivity, specificity, and selectivity (ability to discriminate new compounds or differentiate structurally similar isomers) — and the levels of qualitative and quantitative analysis required to address specific criminal justice questions and their respective laboratory workloads. Laboratories must also consider local drug markets and potential emerging drug threats to determine the most appropriate instrumentation, or even the implementation of new instrumental technologies, to effectively meet testing demands.

FTCoE Best Practices Guidance for Advancing Research Initiatives and Combatting the Synthetic Drug Epidemic Webinar Workshop Series

The National Institute of Justice's (NIJ's) Forensic Technology Center of Excellence (FTCoE), led by RTI International, partnered with the Center for Forensic Science Research and Education to deliver a series of three online workshops in July 2018. These workshops provided insight into the challenges forensic laboratories face with respect to analysis and interpretation of findings involving novel psychoactive substances (NPS). Each workshop, archived on the FTCoE website, runs approximately four hours long and provides resource materials. [243] The workshops also promote a better understanding for the forensic science practitioner community about evidence-based best practices regarding the synthetic drug epidemic. The series focuses on topics such as cross-discipline information sharing, stakeholder outreach, diagnosis and treatment, and cause-of-death determinations.

The following three sessions are part of the workshop series:

- Session I: The Synthetic Drug Crisis — Identifying NPS in Forensic Casework
- Session II: Analysis of NPS — Practical Considerations and Analytical Approaches
- Session III: Interpretive Toxicology for NPS in Forensic Casework

The following list of instrumentation identified by the forensic community includes examples of techniques that can be applied to comprehensively identify controlled substances in seized drug or toxicology samples: [236]

- Gas Chromatography-Mass Spectrometry (GC-MS)
- Gas Chromatography-Infrared Spectrometry (GC-IR)
- Liquid Chromatography Tandem Mass Spectrometry (LC-MS/MS)
- Mass Spectrometry Techniques and Analyzers
  - Electrospray Ionization (ESI)

  - Atmospheric Pressure Chemical Ionization (APCI)
  - Direct Analysis in Real Time (DART)
  - High Resolution Mass Spectrometry, e.g., Time-of-Flight (TOF)
  - Ion Trap Mass Spectrometry Analyzers
  - Triple Quadrupole Analyzers
- Automated Sample Preparation and Extraction Techniques
  - Robotic Platforms
- Nuclear Magnetic Resonance Spectrometry (NMR)

FTCoE Webinar Series: Opioid Crisis — A Public Health Enemy

Rates of opioid use and misuse have reached epidemic proportions and are affecting many aspects of the criminal justice community. Opioid addiction is the driving force behind these increases, with more than 2.5 million Americans reporting a substance use disorder related to their misuse of prescription pain relievers or heroin in 2015. [242] To address the opioid crisis in the United States, the National Institute of Justice's Forensic Technology Center of Excellence (FTCoE) hosted a 13-part webinar series that brings a multifaceted perspective to how criminal justice disciplines are addressing these challenges, sharing their knowledge, and advancing the field.

This webinar series provides insights from different forensic science professionals — including forensic toxicologists, medical examiners, researchers, and other relevant parties. Some topics include the identification of opioids using high-resolution mass spectrometry (e.g., TOF-MS), the drain on laboratory resources, the industry's response to the opioid epidemic, the North Carolina Statewide Medical Examiner System Laboratory approach, regional fentanyl trends, and safety. All archived webinars can be viewed on the FTCoE website at https://forensiccoe.org/webinar/opioid-crisis-a-public-health-enemy-webinar-series.

Some of these techniques also allow for fast and efficient screening of samples and minimal sample preparation. Other techniques, such as time-of-flight mass spectrometry, allow retrospective data analysis that can help determine if a newly discovered drug was present in prior samples. Laboratories may choose to implement different strategies that enhance specific laboratory operations. [244] While estimated costs are $100,000 to $150,000 for the purchase, installation, training, and maintenance for instrumentation routinely used for drug analysis, more sophisticated laboratory equipment may cost $150,000 to $550,000 depending on laboratory needs and operational requirements for comprehensive chemical characterizations.

A survey administered by the DEA NFLIS reported the types of instrumentation used for toxicology screening and confirmation testing in 2016, as well as the types of testing by drug and drug class. While 89% of responding toxicology laboratories (including public and private laboratories) use mass spectrometry-based screening tests, more than 90% perform initial drug testing by immunoassays, which are based on drug class and may not be reactive to fentanyl-related substances, synthetic cannabinoids, or synthetic cathinones. [244] Toxicology laboratories may have unique testing needs beyond standard panels, particularly when testing for nonroutine drugs and analogues. A separate survey of ME/C offices conducted by DEA NFLIS reported on the frequency of toxicology testing of specific drugs or drug classes, as well as frequency of quantitative analysis. While over 75%

The Drug Enforcement Administration's Synthetic Opioids Real-Time Communication Network

The Drug Enforcement Administration (DEA) Synthetic Opioids Real-Time Communication Network, administered by the DEA Southeast Laboratory, connects forensic chemists, toxicologists, coroners, medical examiners, and other stakeholders to address the analytical challenges associated with emerging and novel synthetic opioids. Through this growing network of members from across the United States and around the world, scientific data and analytical approaches are being shared for the detection and identification of synthetic opioids, many of which are structurally similar substances. The network's collective scientific expertise across various disciplines is a powerful tool in overcoming the analytical difficulties associated with new and emerging compounds as they are being analyzed.

Seized-drugs chemists, medical examiners, coroners, and toxicologists are able to quickly communicate questions and tap into an abundance of existing forensic knowledge regarding the analysis of synthetic opioids in overdose deaths and driving under the influence cases. For example, a toxicologist or a seized-drugs chemist in an area where fentanyl analogues are just emerging may ask for information on how to address analytical challenges with the instrumentation and equipment available in their laboratories. Network members (possibly other toxicologists or seized-drugs chemists) respond to the query, providing recommendations and sharing their own experiences in real time.

The assistance provided through this network helps laboratories (federal, state, local, and private) rapidly identify unknown substances, highlight challenges associated with low-level and underreported substances, and facilitate a collaborative effort in combating the opioid crisis. For access to and participation in this network, send a request to Synth-Opioids@usdoj.gov.

of responding ME/C offices reported always testing for alcohol, amphetamines, cocaine, and opioids (other than heroin or fentanyl), only between 51% and 75% always conduct testing for heroin, fentanyl, fentanyl-related substances, and marijuana/THC. Less than 50% always test for synthetic cannabinoids and synthetic cathinones. [147] ME/C offices most frequently conduct quantitative toxicology testing for alcohol; over 75% of responding ME/C offices always conduct this testing, while 51% to 75% of respondents always conduct quantitative testing for the overwhelming majority of other drug classes. Synthetic cannabinoids were a key drug class where 50% of respondents or less always conduct quantitative testing. Both forensic laboratories and ME/C offices may need to consider modifications to their testing strategies based on local drug trends and emerging drug threats, and consider the capabilities of available analytical instrumentation to meet both public safety and public health testing needs.

LSPs reiterated that drug and toxicology analysis is hindered by the lack of reference materials necessary for the identification of these chemicals, which echoes the findings of the President's Opioid Commission report. [149] The DEA laboratory system may provide authenticated reference materials that are not commercially available to forensic laboratories on request through the Reference Materials program. [241, 245] The CDC provides funding and reference laboratory support for the Laboratory Response Network for Chemical Threats (LRN-C) through a Public Health Emergency Preparedness cooperative agreement. The LRN-C is composed of approximately 45 public health laboratories across the United States that provide laboratory response capabilities for chemical emergencies. The CDC recently made methods for the analysis of fentanyl, fentanyl analogues, and other drugs of abuse in blood and urine samples available to LRN-C participating laboratories that can adapt CDC methods to meet the specific needs of their jurisdiction. [246, 247] The CDC is also preparing to offer fentanyl analogue reference material kits to DEA-registered laboratories within the next year to support detection of emerging opioids; see CDC's Traceable Opioid Material Kits webpage. [248]

There are also safety concerns for forensic science personnel who handle unknown substances, particularly at crime or death scenes, but also within the laboratory environment. Recent studies provide a better understanding of drug background levels and guidance for forensic workflow and cleaning protocols in various environments. Forensic agencies may need to update their policies and protocols to prevent and mitigate potential exposures to hazardous substances and ensure availability of personal protective equipment (PPE) and even deployment of naloxone to evidence collection and processing environments. [249, 250] Forensic agencies can also review the *Fentanyl Safety Recommendations for First Responders* issued in 2017, recent information provided by the National Institute for Occupational Safety and Health, and the fentanyl safety video produced by U.S. Customs and Border Protection. [251-253] Forensic laboratory data can also be critical for identifying potential or actual occupational exposures of public safety and public health personnel, and forensic data sharing can inform and mitigate the risk of unintentional work-related exposures. [254-257]

3. Public Safety and Public Health Information Sharing

Timely communication of drug trends can be invaluable for directing additional forensic analysis strategies and decisions about test methods and informing multidisciplinary efforts to address the opioid crisis and any other emerging drug threats. This approach is particularly important for addressing the emergence of NPS, as the chemical structures of NPS are designed to stay ahead of federal and international laws. [149] For example, data generated by drug/controlled substance units can identify emerging drug trends within a jurisdiction, which can subsequently guide toxicology testing and investigations of drug overdose deaths. A common operating picture for the opioid crisis, or any emerging drug threat, can be best understood by considering multiple datasets to develop a real-time surveillance strategy and identify trends and hotspots occurring at the national, state, local, and tribal levels. [149, 157] Recent studies have suggested adopting holistic analytical approaches that use drug chemistry data (both on-site/preliminary data and laboratory confirmations), and antemortem and postmortem toxicology data. [157] Comprehensive toxicology data from cases of driving under the influence of drugs and motor vehicle fatality cases may also provide more information on the prevalence and use of opioids, fentanyl, and other analogues. [258, 259] LSPs noted that building partnerships with existing networks and collaborations, such as local High Intensity Drug Trafficking Area (HIDTA) programs and New York City's RxStat, can be mutually beneficial for understanding local drug threats. [213, 260] For examples of information sharing and practitioner engagement, see the sidebars, "The Bureau of Justice Assistance's Comprehensive Opioid Abuse Program," "Overdose Detection Mapping Application (ODMAP)," and "National Drug Early Warning System (NDEWS) — Resources for Crime Laboratories and Medical Examiner/Coroner Offices."

National Drug Early Warning System (NDEWS) — Resources for Crime Laboratories and Medical Examiner/Coroner Offices

The National Institute of Health's National Institute on Drug Abuse (NIDA) funded the National Drug Early Warning System (NDEWS) Coordinating Center at the University of Maryland's Center for Substance Abuse Research (CESAR) in 2014. Projects at the NDEWS Coordinating Center detect, monitor, and address changing drug trends and emerging drugs in the United States. The center has implemented a number of initiatives, which include maintaining 12 sentinel community sites, conducting local "HotSpot" studies, identifying new psychoactive substances through state-of-the-art biological testing, and expanding communication and information sharing among scientists, practitioners, and concerned citizens through

National Drug Early Warning System (NDEWS) — Resources for Crime Laboratories and Medical Examiner/Coroner Offices (continued)

the NDEWS Network. Since the launch of NDEWS, its staff have worked closely with forensic laboratories and medical examiner/coroner (ME/C) offices to understand current testing capabilities and limitations, provide expanded testing to describe recent drug use and the limitations of existing testing protocols, and encourage information sharing and discussion about drug toxicology. These resources are provided through three innovative approaches to substance misuse epidemiology and communication: the NDEWS Network, HotSpot studies, and the Drug Outbreak Testing Service (DOTS) pilot study. CESAR also runs the Community Drug Early Warning System (CDEWS), sponsored by the Office of National Drug Control Policy, which offers the opportunity for biological testing of larger numbers of specimens to provide a snapshot of recent drug use among populations served by participating programs (primarily related to criminal justice). These four approaches are described in the following sections.

NDEWS Network

The NDEWS Network now has more than 1,000 members, including experts in medicine, toxicology, ethnography, epidemiology, law enforcement, drug policy, and many other fields, as well as concerned citizens. Members of this open community use the network to join cross-disciplinary discussions in toxicology, epidemiology, and drug policy. Toxicology discussions have focused on announcements of newly identified novel psychoactive substances (NPS), the detection of drugs in blood and urine, new drug combinations, and new federal resources. In addition to getting rapid access to information on emerging drugs and trends, members can use the network to explore recent research findings, learn about successful local solutions, and ask others about best practices in testing and addressing emerging trends. To be a part of the discussion, join the NDEWS Network at https://ndews.umd.edu/resources/join-ndews-network.

HotSpot Studies

HotSpot studies are 6- to 8-month, community-based studies planned and conducted by local scientists and practitioners who collaborate to examine drug outbreaks and increases in the harmful consequences of drug misuse. The first NDEWS HotSpot study examined increases in fentanyl-related overdose deaths in New Hampshire. This HotSpot involved three component studies: an in-depth analysis of data and toxicology results from the New Hampshire Office of the Chief Medical Examiner for 505 fentanyl-induced overdose deaths from 2015 to September 2016, expanded urinalyses of 136 decedents, and interviews with 12 first responders and 20 recent drug users. The New Hampshire HotSpot reports for each of these studies are available on the NDEWS website at https://ndews.umd.edu/publications/landingtopic/hotspot-reports.

Two additional HotSpot studies are currently underway. The Cuyahoga County, Ohio, HotSpot is examining heroin, fentanyl, and related poly-drug use in opioid injection drug users. This study involves conducting expanded urinalyses of specimens provided by two local public health programs and interviews with first responders and recent drug users. The Minnesota HotSpot study is examining the feasibility of developing and implementing a model for fatality reviews of opioid overdose deaths with a rural northern Minnesota tribe. Local collaborating scientists will work with the tribe to develop the research model and conduct approximately 12 fatality reviews.

Drug Outbreak Testing Service (DOTS) Pilot Study

Drug treatment programs, medical examiners/coroners, and hospitals often do not have the means to test their urine specimens for the latest NPS and emerging drugs. The DOTS pilot study was designed to provide local collaborators (ME/C offices and hospitals) with a relatively quick snapshot of the types of drugs recently used by patients and decedents. DOTS provides expanded one-time testing of up to 20 de-identified urine specimens for approximately 240 drugs at no cost to participating sites. All testing is conducted by the NDEWS collaborating laboratory — the Armed Forces Medical Examiner System (AFMES) — which is a member of the NDEWS Scientific Advisory Group. The DOTS test results are used for epidemiologic purposes to describe local drug use. The results are not intended for use in clinical or legal proceedings. The DOTS pilot study is exploring the best ways to recruit sites and to make the test results most useful to the submitting sites. Results have now been released for seven DOTS sites. Information on becoming a DOTS site and *DOTS Bulletins* for completed sites are available on the NDEWS website at https://ndews.umd.edu/drugs/landingtopic/drug-outbreak-testing-service-dots. To inquire about participating as a DOTS site, contact ndewsdots@umd.edu.

National Drug Early Warning System (NDEWS) — Resources for Crime Laboratories and Medical Examiner/Coroner Offices (continued)

Community Drug Early Warning System (CDEWS)

Through a collaboration with AFMES, CESAR has been able to launch the CDEWS project. Since CDEWS began in 2013, its staff have worked with a broad spectrum of criminal justice and public health programs to provide a relatively quick and inexpensive snapshot of the types of drugs recently used by populations served by participating programs. Approximately 100 to 200 de-identified urine specimens per site, collected as part of routine testing, are tested by AFMES for approximately 240 licit and illicit drugs. Populations studied include adult parolees and probationers, pretrial surveillance subjects, prison inmates, drug court participants, juvenile detainees, and patients from two hospitals who presented with symptoms of drug overdose. CDEWS briefs and reports are available on the NDEWS website at https://ndews.umd.edu/resources/landingtopic/community-drug-early-warning-system-cdews.

The Bureau of Justice Assistance's Comprehensive Opioid Abuse Program

The purpose of the Comprehensive Opioid Abuse Program (COAP), administered by the Bureau of Justice Assistance (BJA), is to provide financial and technical assistance to states, units of local government, and Indian tribal governments to plan, develop, and implement comprehensive efforts to identify, respond to, treat, and support those impacted by the opioid epidemic. There were six application categories in the FY 2018 COAP solicitation, with Category 6 supporting information-sharing partnerships for access to timely and accurate data. COAP's Category 6 — Public Safety, Behavioral Health, and Public Health Information-Sharing Partnerships — provides funding for the formation of a multidisciplinary action group, which may include law enforcement representatives, the state or local health department, state medical and pharmacy boards, prosecutors, medical examiner/coroner offices, forensic science laboratories, probation and parole, drug court representatives, child welfare representatives, local drug treatment providers, and community organizations. One of the allowable uses of COAP funding is to support the timely collection of data from medical examiner and coroner offices, forensic science laboratories (including seized-drug and toxicology units), and crime scenes and combine these data with other datasets, including fatal and nonfatal overdoses and Prescription Drug Monitoring Program records. More information on COAP can be found on BJA's website at https://www.bja.gov/ProgramDetails.aspx?Program_ID=72.

Overdose Detection Mapping Application (ODMAP)

In an effort to understand and mobilize against the opioid crisis currently plaguing the United States, the Washington/Baltimore High Intensity Drug Trafficking Area (W/B HIDTA) program developed the Overdose Detection Mapping Application Program (ODMAP). ODMAP provides near real-time surveillance data of suspected overdoses across jurisdictions to support public safety and public health efforts to mobilize an immediate response to a sudden increase, or spike, in overdose events. ODMAP links first responders and relevant record management systems to a mapping tool to track overdoses and stimulate a real-time response and strategic analysis across jurisdictions. Laboratories and medical examiner/coroner (ME/C) offices should consider outreach to their local public safety and public health partners to identify collaborative efforts to use ODMAP data and additional proactive, analytical strategies. These partnerships may provide an opportunity for laboratories and ME/C offices to provide direct feedback to ODMAP partners on the results of drug and toxicology analysis and death investigations.

ODMAP launched in January 2017 with three pilot sites. Currently, there are nearly 1,300 agencies in 45 states that are utilizing the tool, and more than 70,000 overdoses have been entered into the system. Due to the success of the program, the community of ODMAP users has developed significantly. Products of this community include a monthly webinar series, an online repository for material developed by users, weekly interactive demonstrations, and a monthly newsletter. The goal is to further support and facilitate collaboration, communication, and coordination within the community.

For more information on ODMAP, visit the W/B HIDTA website and the ODMAP YouTube Channel, or see the ODMAP Training Manual. See the recent NIJ Notes from the Field series for recent success stories: ODMAP: A Digital Tool to Track and Analyze Overdoses [261]

These forensic data provide a comprehensive view of the opioid crisis, and timely access to these data is essential for identifying drug trends and helping public safety and public health stakeholders develop interdiction and intervention strategies. The Opioid Commission report indicates that data collection activities must be strengthened to enable real-time surveillance of the opioid crisis at the national, state, local, and tribal levels. [149] As drug detection technologies become more portable in the field, forensic laboratories have greater opportunities to partner with law enforcement agencies to generate preliminary data and actionable information. Early drug detection in the field can help identify potentially hazardous materials and support triaging and prioritizing of casework to increase efficiencies. Implementation of these technologies by law enforcement should be considered in coordination with a forensic laboratory, which can provide operational management and oversight. In 2018, the NIJ FTCoE published the "Landscape Study of Field Portable Devices for Presumptive Drug Testing," a report to inform the forensic community of the benefits, limitations, and implementation considerations for various technologies, including mass spectrometry (MS), ion mobility spectrometry (IMS), Raman spectroscopy, infrared (IR) spectroscopy, and color-based testing techniques (see the sidebar, "FTCoE Landscape Study of Field Portable Devices for Presumptive Drug Testing," for more information). [262] Other promising techniques, such as direct analysis in real-time mass spectrometry (DART-MS), can increase testing sensitivity to identify highly potent components within drug mixtures. [263] Some forensic laboratories have established field detection programs to develop actionable information and increase casework efficiencies. (See the sidebar, "Phoenix Police Department Controlled Substances Field Identification Program.")

FTCoE Landscape Study of Field Portable Devices for Presumptive Drug Testing

As the incidence of dangerous substances, such as fentanyl analogues, rises at alarming rates, the need for quicker detection, increased safety measures, and more robust technologies becomes more critical. The National Institute of Justice's (NIJ's) Forensic Technology Center of Excellence (FTCoE), led by RTI International, performed a landscape study — alongside law enforcement, the forensic community, and various instrument manufacturers — of portable, hand-held devices that can be used for presumptive drug testing of controlled substances in the field. The resulting report provides a comprehensive overview of currently available methods and technologies for field-based presumptive drug testing. The objective of the report is to alert end users of the products available, and help them make better-informed purchasing decisions. The report is available at https://rti.connectsolutions.com/alsfpd.

Phoenix Police Department Controlled Substances Field Identification Program

The Phoenix Police Department's Controlled Substances Field Identification program was piloted in 2000 using colorimetric testing to test for suspected marijuana, cocaine, and methamphetamine. The program in this form was used as the model for the Field Investigation Drug Officer (FIDO) program. [264] As arrests for heroin and other opiates increased, the Phoenix Police Department Crime Laboratory began to investigate if Raman spectroscopy would allow for the testing of black tar heroin. After the laboratory conducted an extensive validation of a hand-held Raman spectrometer, they determined that 21 controlled substances could be accurately and reliably identified by this device. The device was then piloted in the field by a small group of trained officers who were able to use it accurately, efficiently, and reliably.

The Phoenix Crime Laboratory is responsible for training officers to use the Raman device and also oversees the program, which includes stringent quality control. The devices are placed at precincts, where only trained and certified officers are allowed to use them to perform drug testing. The devices cost approximately $20,000 each, and there is an additional cost for the annual maintenance agreement. Ten devices were finally deployed citywide in November 2015. When using only colorimetric chemical test kits, the trained officers were testing approximately 400 to 500 suspected controlled substance items each

Phoenix Police Department Controlled Substances Field Identification Program (continued)

month. Since implementing the Raman devices citywide, the trained officers test an average of 650 to 700 suspected controlled substance items each month. The officers' preliminary testing can be used to file charges for a case, which often results in the resolution of the case upon plea. This program reduces the number of submissions to the laboratory. If the case proceeds to trial, the laboratory will then conduct a full analysis.

The Raman device is not used for analysis of marijuana; chemical colorimetric testing is still used to test marijuana samples. The program's stringent quality control has maintained the integrity of the program for almost 20 years.

4. The Potential Impact of the Legalization and Decriminalization of Marijuana on State and Local Crime Laboratories

Many states are considering the legalization and decriminalization of marijuana for recreational and medical use, but there have been no extensive studies to understand the affect this may have on state and local crime laboratories. Limited anecdotal information suggests that crime laboratories may experience mixed outcomes in states where decriminalization or legalization has occurred. Crime laboratories have also expressed concern that permitted production of hemp could have a drastic impact on laboratory testing of seized drugs, if quantitative testing is required to determine the percentage of THC in a product to differentiate it from hemp. [265]

Some jurisdictions have experienced a reduction in backlog after changes in marijuana laws. Not only do forensic chemists analyze suspected controlled substances, but they are also required to travel to court in cases where they are likely to testify, which prevents them from focusing on casework. In September 2017, New Hampshire eliminated jail time for the possession of a small amount of marijuana, which resulted in fewer marijuana cases being submitted to the laboratory. This change, in conjunction with the hiring of additional drug chemists, reduced the backlog of suspected controlled drug cases from 3,600 to 1,600 in a period of six months. [266]

At the same time, changes in marijuana laws can create new challenges. NIJ's Forensic Science Technology Working Group, a committee of approximately 50 experienced forensic science practitioners from local, state, and federal agencies and laboratories, convenes an annual meeting to identify, discuss, and prioritize operational needs and requirements within the forensic sciences. One of the high-priority needs that has been identified is research to establish validated methods for quantitating THC from plant materials, edibles, and extracts. [267] The Denver Police Department Crime Laboratory submitted a research proposal to NIJ to develop and validate new methods for extracting and quantitating THC from commonly encountered edible marijuana products. The process of developing a method and then validating it for use in an accredited laboratory to ensure scientific accuracy and reliability is time-intensive and requires significant manpower and financial resources. In its proposal, the Denver Police Department Crime Laboratory stated that "[b]ecause of efforts for the continued expansion of the legalization of Marijuana on the state level, the ability to quantitate THC concentration in infused and edible products is an essential service that many analytical forensic laboratories will be required to provide." Furthermore, laboratories may have to develop multiple new methods for processing edibles because they can be submitted to the laboratory in various forms. In their research

proposal, the Denver scientists proposed focusing on five types of samples: baked goods, chocolates, candies, tinctures, and beverages. [268]

In other research funded by NIJ, Virginia Commonwealth University is focusing on quality control materials and sample preparation for marijuana-infused products with respect to toxicological analysis. As submitted by the proposer: "The local legalization of marijuana within the United States for both medicinal and recreational use has increased. Currently, marijuana is legal in some form in 29 states and the District of Columbia. Marijuana is classified as a Schedule 1 substance by the U.S. Drug Enforcement Administration (DEA). The U.S. Food and Drug Administration (FDA) does not regulate or enforce manufacturing of marijuana or marijuana products other than Marinol®. Marijuana-infused products such as candies or baked goods contain psychoactive cannabinoids… [t]he testing results of these products may come into question as a result of limited published data which evaluate the stability of the psychoactive cannabinoids in these matrixes. The Scientific Working Group for Forensic Toxicology (SWGTOX) and FDA guidelines require that samples are analyzed using matrix matched calibrators and quality control materials whenever possible." [269] Not only is it a challenge to develop and validate a new method for the analysis of edibles, but the method could require new instrumentation, retraining of drug chemists, and additional competency and proficiency testing.

Finally, this needs assessment was unable to identify any studies with a focus on how marijuana legalization might impact forensic laboratories and ME/C systems, including driving safety and DWI cases. As jurisdictions consider legalization of marijuana, DWI arrests and driving fatalities may increase, creating a burden on laboratories responsible for toxicology testing and a larger caseload for ME/C offices.

B. Digital and Multimedia Evidence

Needs:

- Resources and staffing to address the dramatic growth in digital and multimedia evidence (DME), now common for every case.
- Resources to purchase and maintain costly hardware and software tools and associated software licenses.
- Infrastructure for data storage of digital evidence to provide sufficient capacity and security to address operational requirements for data analysis and data sharing.
- Training for investigators and prosecutors to inform DME requests, increase understanding of the aspects of digital evidence, calibrate expectations, and produce meaningful DME results for developing investigative leads and for court cases.
- Dedicated personnel for DME casework and frequent training to stay current with new and emerging technologies.

Challenges:

- Increased prevalence of encryption methods and encrypted devices and applications can be an impediment to DME investigations.

- DME examinations must continuously respond to new and emerging technologies and devices.
- DME functions may be carried out by personnel on a part-time or collateral duty basis, which can divert focus from the DME mission.
- Recruiting and retaining digital forensics experts is made more difficult by competition with the private sector.

Promising Practices:

- Development of regional centers and task forces that provide resources and model infrastructure, such as the Regional Computer Forensics Laboratories (RCFLs) administered by the FBI and the Internet Crimes Against Children Task Force program (ICAC) administered by the U.S. Department of Justice's (DOJ) Office of Juvenile Justice and Delinquency Prevention (OJJDP).
- Education and training for investigators and prosecutors to identify DME data with potential investigative, probative, or forensic value.
- Introducing triaging workflows across staff levels to examine and preserve evidence at the scene or early in the investigation, identify actionable information, facilitate real-time data analysis, maximize efficiencies, and help DME examiners prioritize casework.
- Dedicated DME personnel, salaries, benefits, and promotion opportunities commensurate with recruitment and retention of DME subject matter experts.
- Investments in DME tools for the examination of new and emerging digital technologies that are also responsive to evidentiary needs.
- Dedicated groups that perform software and tool testing and validation that can be shared with the DME community.
- Education and training to support implementation of quality management systems and accreditation efforts.

Digital forensics shares the same challenges as traditional forensic laboratories — resources, research, personnel, and education — but has unique issues as well. DME encompasses a wide variety of evidence types: computers, cell phones, GPS devices, gaming devices, and other types of data storage drives; audio, video, and image files; and various types of digital and analog media, including magnetic, electric (flash), film, tape, and optical media (e.g., CDs, DVDs). DME also includes data stored on networked servers or cloud storage, and transmitted almost instantaneously through both wired and wireless communications systems. The ubiquity of digital devices, including devices with digital camera and video capabilities, closed-circuit television, and officer body-worn cameras; the advent of device portability and instantaneous sharing via social media; internet-connected devices; and integrated devices such as drones and autonomous vehicles all exemplify the types and quantities of digital data that may provide investigative or forensic value. DME examinations may encounter technological challenges, such as encrypted files or devices, or require additional expertise to examine "dark web" content and cryptocurrency transactions. While the National Research Council's 2009 report *Strengthening Forensic Science in the United States: A Path Forward* (NAS report) treated DME as an emerging forensic science discipline, this field has grown tremendously with the surge along with the growth in data

storage capacities, data speeds, types of data, and the methods through which data can be shared and accessed. [30] As digital data continue to play a prominent role in everyday activities, they will also be critical for investigative and forensic purposes. It is now common for every case to have some form of DME, and most major cases include enormous amounts of data and involve many different types of data and devices. Collecting, processing, and analyzing DME is important for solving crimes and addressing court cases. [270]

One of the keys to understanding the needs of the DME community is to understand the specific processes performed in DME investigations, as well as the specific roles of the personnel conducting each type of process, where the role is typically determined by the education, training, and experience of the personnel. Digital forensics techniques can include collection and recovery, extraction, preservation, and copying, as well as data analysis, authentication, enhancement, and restoration. [271] Some activities tend to support investigative functions through the development of actionable intelligence or investigative leads. These investigative functions may focus on the recognition of digital evidence and data extraction or acquisition and imaging. These tasks can often be performed quickly and efficiently by personnel with basic training, using a conventional set of tools in a forensically sound manner. These tasks can be accomplished within a digital forensics laboratory or even in the field, to effectively and efficiently meet mission goals, such as producing preliminary reports or aiding in evidence prioritization and triaging.

More comprehensive or targeted DME examination processes may include the application of more rigorous digital data analysis tools to identify and interpret probative or evidentiary data. These functions may require personnel to have more extensive education and training. Digital examiners may also be responsible for conducting testing and performance verifications of digital analysis tools, all of which are critical for ensuring that DME tools work appropriately and as intended. Some digital forensics tools, including automated tools and search packages, may be utilized by personnel with either basic or advanced training, in either field triaging or laboratory analysis situations, while other data analysis processes may be more applicable for use in a digital forensics laboratory environment, depending on the level of computing power or infrastructure needed or the type of subject matter expertise required.

The BJS Census of Publicly Funded Forensic Crime Laboratories (Census) has demonstrated that an increasing number of crime laboratories are performing digital evidence functions, from 12% in 2002 to 22% in 2014. [97] This increase in digital evidence functions at crime laboratories corresponds with the increased prevalence of DME available for investigations and court cases, which is likely to continue. There are also stand-alone units within law enforcement agencies that provide DME services and operate separately from or may be associated with the crime laboratory. [13, 21, 60] These digital forensics units are typically small, with only a few analysts, or the digital forensics functions may be performed by sworn personnel on a part-time basis or as a collateral duty. DME personnel may have specialized training or backgrounds in computer science or information technology (IT), or they may start their careers in law enforcement and obtain training, experience, and professional development that provide a digital forensics career trajectory. Digital forensics personnel could be sworn or civilian positions, depending on agency needs or the organizational structure and culture. Non-DME duties, particularly for sworn officers working in DME forensics, may divert personnel from their DME mission. Without a sufficient number of dedicated personnel to address projected levels of crime, DME backlogs will likely increase, affecting the timeliness of DME results.

The 2014 BJS Census showed the number of digital evidence requests to crime laboratories decreasing, from 33,000 in 2009 to 25,000 in 2014. However, the number of backlogged digital evidence cases at crime laboratories jumped from 1,600 in 2009 to 7,800 in 2014. The growing backlog is likely due to the increasing amounts of data from the digital evidence submitted (from hundreds of gigabytes to several terabytes) as well as the complexity of case requests. Crime laboratories also outsourced 15% of digital evidence requests in 2014. [97]

As part of a separate pilot study to expand the scope of information collected about this forensic science discipline and to help inform future data collections, BJS also sent the questionnaire for the 2014 BJS Census to an additional 61 state and federal laboratories that solely analyzed digital evidence and were not among the 409 crime laboratories that met the BJS Census's traditional definition of a crime laboratory. [272] The pilot study also included responses received from 26 separate state and federal laboratories that were among the 409 traditional crime laboratories and that reported analyzing digital evidence during 2014. This study collected data regarding the digital forensic functions performed, as well as the sources of digital information analyzed. (See tables 6 and 7 for a summary of the data.)

In January 2014, RAND and the Police Executive Research Forum (PERF) held a workshop funded by NIJ through the Priority Criminal Justice Needs Initiative to examine challenges associated with digital evidence. Workshop participants also identified needs associated with digital evidence collection, management, analysis, and use and the ability of prosecutors to secure convictions. [270] This activity resulted in the publication of nine specific top-tier needs identified as the highest priority, as well as 25 additional lower-tier needs that, if addressed, could improve the capabilities of the criminal justice system with respect to digital evidence. (See tables 8 and 9).

Several needs raised by LSPs with DME experience aligned with the needs identified in the RAND/PERF effort. LSPs agreed that virtually every case has DME, and while DME personnel's focus continues to be working on priority cases and meeting court dates, DME personnel can also provide valuable assistance to investigators, law enforcement, and legal professionals during the investigation stages. LSPs noted that there is a strong need for customer training, for both investigators and prosecutors, to calibrate expectations, avoid rush jobs, and even help the customer determine if their requests for evidence analysis are technically feasible. [273] Education on what DME data may be of value can help customers identify the level of analysis needed and narrow the specificity of their requests to help achieve impactful results. However, better customer education can also drive increased demand. Customer requests may become too broad in scope, contributing to delays and backlogs.

Small DME units, particularly those with personnel that perform DME on a part-time or collateral duty basis, face increasing backlogs due to personnel shortages. Laboratory management and police executives should be aware that assigning dedicated, specialized personnel to DME functions is optimal for addressing workloads. Lack of personnel may also impact the implementation of quality management systems if personnel are not available to perform technical and administrative peer reviews of casework.

LSPs indicated that sufficient training is a critical need in order for digital examiners to address emerging technologies, maintain currency of the various types of digital forensics tools that are available to examine evidence quickly and efficiently, and be able to recognize relevant, probative digital information (e.g., social media, mobile application databases).

Table 6: BJS 2014 Pilot Study of State and Federal Digital Evidence Laboratories — Forensic Functions Performed

Forensic functions performed	Percentage of individual labs
Computer forensics	87%
Mobile device analysis	93%
Image analysis	70%
Video analysis	75%
Forensic audio	54%
Other DME analysis	11%

Table 7: BJS 2014 Pilot Study of State and Federal Digital Evidence Laboratories — Source of Digital Information Analyzed

Source of digital information analyzed	Percentage of individual labs
Traditional cellphones	89%
Smartphones	91%
Laptops, tablets, and desktop computers	87%
Thumb and external drives	89%
Wireless routers and network devices	70%
GPS and navigation systems	77%
Audio files	70%
CDs, DVDs, and other storage mediums	87%
Gaming systems (e.g., Xbox, Playstation)	79%
Cloud and server data	67%

[273] Expert witness training is also critical so that DME professionals can educate the courts and successfully convey DME results. Continuous education and training are critical to address new types of DME, such as connected and wearable devices or onboard vehicle devices, and to implement new DME techniques to enable data extractions, such as "chip-off" and JTAG connection techniques.[12] LSPs noted that personnel sometimes pay for their own continuing education and training. LSPs also noted that the purchase and maintenance of hardware and software tools and the associated software licenses (as well as the number of licenses needed) can be costly, and that management and police executives need to understand the return on investment for training and resource purchases. LSPs indicated that coordination with their agency's IT personnel is also essential, as IT security protocols and firewalls may prevent DME examiners and prosecutors from using the necessary software or web-based platforms to view evidence or examine web content. LSPs indicated that robust digital evidence data storage infrastructure and strategies are needed to ensure sufficient storage capacities for the increasing amounts of digital data evidence and analysis of large datasets (i.e., "big data"), provide sufficient security for evidence preservation, and address specific operational requirements, such as the ability to index, access, query, and share information among law enforcement partners. [274]

[12] Chip-off is when the memory of a device is physically removed. Joint Test Action Group (JTAG) is the common name for what was later standardized as the IEEE 1149.1 Standard Test Access Port and Boundary-Scan Architecture, devised for testing interconnects on printed circuit boards implemented at the integrated circuit (IC) level.

The Bureau of Justice Assistance (BJA) Law Enforcement Cyber Center (see the sidebar, "Bureau of Justice Assistance Law Enforcement Cyber Center (LECC)") also offers a "Cyber Report Card" self-assessment for managers. There are several organizations that provide recommendations for cybersecurity and incident response and reporting, particularly through the Department of Homeland Security's National Cybersecurity and Communications Integration Center (NCCIC). [275-278]

LSPs also echoed the need for methods, tools, and training to triage DME, so that front-line personnel who respond to crime scenes or work in the field can utilize appropriate tools that provide actionable information early in an investigation and facilitate real-time data analysis, particularly for major investigations. Triage workflows can also be implemented through systems-based approaches to help DME examiners prioritize caseloads. Triaging tools are particularly important for cases with large amounts of data or video footage. LSPs noted that laboratory information management systems (LIMS) can also be used to effectively manage caseloads and develop performance metrics.

LSPs noted the need for the regionalization of resources and institutionalized training. Regional DME task forces composed of federal, state, and local personnel have served as models to coordinate resources and responses. [273] The FBI's RCFLs provide digital services, training, forensic tools, and court testimony support through partnerships with state and local agencies. (See the sidebar, "Regional Computer Forensic Laboratory — Training in Digital Evidence.") Participating agencies have noted that RCFLs provide enhanced computer forensic capabilities and the opportunity to leverage the resources of the FBI, including current training and technology, priority service, and additional DME personnel assistance on search warrants. [279] Although some RCFLs have reported backlogs, others, such as the Philadelphia RCFL, demonstrate timeliness in completing forensic examination requests with results that meet partner expectations and have been recommended as a resource to other law enforcement agencies. OJJDP also administers ICAC, which supports a national network of 61 coordinated task forces representing federal, state, and local law enforcement and prosecutorial agencies. Through training and the development of investigative tools and techniques, the ICAC network supports investigations and prosecutions of persons involved in child abuse and exploitation cases involving the internet. For more information on ICAC, see the sidebar, "The Office of Juvenile Justice and Delinquency Prevention's Internet Crimes Against Children Task Force Program."

Tool testing and validation is also an issue for DME units. Vendors of commercially available digital forensics tools frequently provide updates for the tool's software (on an annual or even monthly basis), and digital examiners sometimes develop their own tools as solutions to address case-specific needs. LSPs noted that DME examiners must test and validate their DME tools in a timely and consistent manner in order to verify their suitability for use in casework. LSPs suggested that federated testing programs can centralize the tool testing process and distribute the workload to address the timeliness of robust testing, so that individual examiners can instead dedicate their time and resources to their casework.

Two federal agencies sponsor testing programs for digital forensics tools and post results for federal, state, and local DME examiner use. The U.S. Department of Defense Cyber Crime Center (DOD DC3) publishes a list of validation and test reports for several commercial off-the-shelf and government off-the-shelf digital forensics software tools, including tools

Regional Computer Forensic Laboratory — Training in Digital Evidence

The Regional Computer Forensic Laboratory (RCFL) program was established in 2002 and funded by the United States Congress under the auspices of the FBI, to provide high-quality, uniform computer forensics support to other federal, state, and local criminal and national security investigations.[1] It is a highly successful and fully accredited partnership between the FBI and federal, state, and local law enforcement agencies across the United States. RCFLs provide state-of-the-art digital forensic services, court testimony, search assistance, education, and training to both participating and nonparticipating agencies within the geographic regions they serve. The FBI provides training, equipment, and initial leadership to the RCFLs. State and local participating agencies provide staff and have a stake in the leadership of the RCFLs. Over half of the digital forensic examiners in the RCFLs are from other federal, state, and local partner agencies. There are currently 16 RCFLS in the country, serving 5,000 law enforcement agencies in 19 states. The key goals of the RCFL program are to:

- Provide timely, professional, and technically advanced digital forensics services to the law enforcement agencies in a laboratory's service area.
- Fully utilize legal, applied science, and engineering capabilities to support digital forensics examinations.
- Increase the confidence of investigators, prosecutors, and judges in the digital forensics examination discipline through standardized training and forensics protocols.
- Provide responsive and flexible services in support of diverse investigative programs.
- Meet legal and administrative requirements of diverse judicial systems.
- Provide digital forensics training to law enforcement personnel upon request.

During the program's more than 18 years of operation, RCFLs have significantly contributed to a wide variety of high-profile cases, including the evidence examination from the 9/11 investigation, the Enron Task Force, the Boston Marathon bombing, the shooting at San Bernardino, and thousands of lesser-known cases protecting children and the community. Below are some examples of how RCFLs provide support to local, state, federal, and international partners:

Providing Round-the-Clock Support to Communities in Times of Crisis

The Orange County RCFL provided critical digital evidence support to the investigation in the aftermath of the December 2, 2015, shooting at the Inland Regional Center in San Bernardino that killed 14 people and wounded 21. RCFL staff provided on-site and laboratory assistance in processing the many devices related to the attack. "We ran a 24/7 operation for the roughly two and a half weeks of the critical phase of the investigation," explained the director of the Orange County RCFL.

Greater Houston RCFL Helps Identify Police Officer's Murderer Using Digital Evidence

A man who killed a police officer was identified through the help of the Greater Houston RCFL. The subject began making complaints about members of law enforcement after a disagreement with his ex-wife over family photographs. After his complaints with the internal affairs department went nowhere, he then made a list of law enforcement personnel whom he accused of corruption, including Assistant Chief Deputy Clint Greenwood, who headed Internal Affairs from 2013 to 2016. The subject shot and killed Greenwood on April 3, 2017. The subject then killed himself the following day. With the RCFL's help in conducting forensic examinations and submitting evidence, investigators identified the man within a week.

For more information, visit https://www.rcfl.gov/training.

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[1] The USA PATRIOT Act (U.S. H.R. 3162, Public Law 107-56), Title VIII, Section 816 specifies the development and support of cybersecurity forensic capabilities. It directs the attorney general to establish RCFLs that have the capability of performing forensic examinations of intercepted computer evidence relating to criminal activity and cyberterrorism; the capability of training and educating federal, state, and local law enforcement personnel and prosecutors in computer crime; and the capability to "facilitate and promote the sharing of Federal law enforcement expertise and information about the investigation, analysis, and prosecution of computer-related crime with State and local law enforcement personnel and prosecutors, including the use of multijurisdictional task forces." Fifty million dollars were authorized for establishing such laboratories.

Table 8: Top-Tier Digital Evidence Needs From RAND

Problem or Opportunity	Associated Needs
Prosecutors have a tendency to request all information off devices without considering the challenge posed by large volumes of data.	Expand available federal-level training at existing training schools to build knowledge across systems.
First-responding officers to an incident or arrest often do not know how to secure and use digital evidence to preserve chain of custody and later admissibility in court (e.g., "a detective searching a computer on his own").	Integrate digital evidence practices into academy training — at least at the awareness/basic training level.
Departments do not have enough personnel to process volume of digital evidence, no matter what tools are used, resulting in large backlogs.	Develop better prioritization or triaging methods or tools for cases and for what evidence to extract within cases (either for digital evidence examiners or potentially tools usable by officers in the field).
Smaller departments lack capacity to address digital evidence.	Develop regional models for building capability where small departments pay to fund common resources. Incentives could be created through grant mechanisms to facilitate this approach.
The acceptability of results of digital evidence analysis can be challenged in court when extraction and analysis are not performed with the most up-to-date tools.	Routinely update the training and tools available to examiners to ensure they are using the current technology.
Lack of knowledge about digital evidence on the part of judges complicates appropriate use in court.	Expand available federal-level training at existing training schools to build knowledge across systems.
Departments lack tools to represent complex datasets in understandable ways for investigation and presentation.	Utilize existing software tools for analysis of datasets like cell tower data. Examples exist that are web-based and can be bought on a case-by-case basis, but knowledge of what is available is limited.
Volume of data coming from closed-circuit television cameras and video is a challenge—and there are limited tools for evaluating and processing evidence.	Departments must acquire in-house tools to process video evidence.
Collecting digital evidence from victims' devices — where broad capture of all data on a phone must capture data law enforcement "doesn't want" (e.g., sexting materials) — can be problematic.	Develop tools that allow more narrow collection of data from devices to respect victim privacy while still meeting investigative or protective needs.

Source: Digital Evidence and the U.S. Criminal Justice System [270]

Table 9: Lower-Tier Digital Evidence Needs From RAND

Problem or Opportunity	Associated Needs
Departments do not have enough personnel to process volume of digital evidence, no matter what tools are used, resulting in large backlogs.	Increase sworn personnel devoted to digital forensics activities; define roles for lower-paid "digital evidence assistants" who can perform routine examinations; and address pay scale issues to make it possible to successfully recruit civilian staff for technical roles.
Some GPS devices available on the market use proprietary software and access technologies that make it difficult to extract data during investigations.	Utilize alternative approaches to acquire data from the company (e.g., execute search warrants on companies for data that these devices transmit to company servers) rather than focusing on the devices themselves.
Encryption and passwords on mobile phones prevent access.	Develop alternative access methods to address encryption.
It can be difficult to access on-car digital evidence from systems such as OnStar (and other devices that cannot be removed from the platforms).	Develop tools to allow easier access to that data without disassembling/destroying devices, while also maintaining chain of custody.

Table 9: Lower-Tier Digital Evidence Needs From RAND (continued)

Problem or Opportunity	Associated Needs
Managing multiple video evidence streams (e.g., business closed-circuit television, personal cell phone videos) during large incidents poses a data management and analysis challenge.	Develop information systems to better manage data, link with metadata, etc. to allow searchability and analysis.
Having to pay for access to historical datasets of public data (e.g., Craigslist posts) poses a cost challenge for departments.	Build a public-access dataset for law enforcement for investigative purposes that captures and archives such data.
The performance and acceptability of new evidence collection and analysis techniques for criminal justice are uncertain.	Provide timely validation/evaluation of technologies and analysis types of different products and techniques against established standards.
Departments face real difficulty in maintaining capability to collect and analyze digital evidence given the pace of technological change.	Develop more standardized certifications for digital forensics personnel, including continuing education requirements.
Need ways to collect "routine" digital evidence in a way that does not require full examiner involvement and does not always require seizure of the device (e.g., from a crime victim).	Develop deployable tools for detectives to collect evidence in the field, designed in a way that addresses potential for misuse and appropriately controls information and access.
Current tools for explicit image detection are ineffective.	Enhance explicit image detection to narrow how many images need to be reviewed by examiners.
The practice of "promoting out" staff from digital evidence units poses a problem for agencies to maintain technical proficiency.	Create a promotion track within specialist units.
Investigators may have no way to identify that data in suspect or victim cloud storage accounts exist and could provide investigative leads.	Develop tools to identify where accounts exist to trigger follow-up investigation.
Some courts are skeptical of digital evidence due to uncertainties about chain of custody and validity of information obtained from devices.	Need an effort to systematically validate the performance of digital evidence tools to ensure they can withstand *Daubert* challenge.
Law enforcement lacks tools to analyze some types of electronic systems and devices.	Develop digital evidence tools for examining gaming devices, networks, and routers.
Proprietary codices for video evidence can create analysis problems.	Though commercially available video conversion tools allow conversion through screen capture, improvements that reduce the time required for such conversion would be valuable.
Technologies developed to address problems have a "whack-a-mole" character trying to catch up with innovation.	Consider prize models to create incentives for many different private sector actors to work on different digital evidence problems simultaneously.
Issues that cross international borders create significant challenges for issuing and serving warrants for electronic information from entities in other countries.	Improve efficiency of MLAT processes for requesting information from foreign entities.
Agency budget constraints make it difficult to maintain the currency of digital evidence tools and software packages.	Develop low-cost or free digital evidence analysis tools.
Virtual currencies pose challenges for investigations.	Develop tools to identify presence of virtual currency on seized devices.
Within agencies, a lack of leadership commitment to sufficiently funding digital evidence analysis capacity limits the ability to build and maintain expertise.	Develop information to make the case for building and maintaining digital evidence analysis capability outside of federal grant streams, preparing departments for making the transition to funding these capabilities internally.
Quality of video evidence can limit use of other analytic tools (e.g., facial recognition).	Develop information to help persuade entities to adopt better video technologies to broaden technology options for analysis.

Source: Digital Evidence and the U.S. Criminal Justice System [270]

The Office of Juvenile Justice and Delinquency Prevention's Internet Crimes Against Children Task Force Program

Over the past two decades an increasing number of children and teenagers have been using the internet, leading to a rise in child sexual abuse images available electronically and heightening online activity by predators seeking unsupervised contact with potential underage victims. To address this issue, the Office of Juvenile Justice and Delinquency Prevention (OJJDP) developed the Internet Crimes Against Children Task Force (ICAC) program. The ICAC program is a national network of 61 coordinated task forces representing over 4,500 federal, state, and local law enforcement and prosecutorial agencies. These agencies provide forensic and investigative components, training and technical assistance, victim services, and community education to help states and local governments respond to online child victimization.

Since the inception of the ICAC program in 1998, over 629,400 law enforcement officers, prosecutors, and other professionals have been trained on techniques to investigate and prosecute ICAC-related cases. Additionally, over 775,000 complaints of alleged child sexual victimization have been reviewed since 1998, resulting in the arrest of more than 83,000 individuals. In 2017 alone, the ICAC task force network conducted more than 66,000 investigations and 86,400 forensic exams, which resulted in arrests of more than 10,300 individuals.

For information on ICAC task forces by state, visit www.icactaskforce.org.

developed by DOD DC3.[13] [280] The Computer Forensics Tool Testing (CFTT) project at NIST established a methodology for testing computer forensics software tools by developing general tool specifications, test procedures, test criteria, test sets, and test hardware. [281] The results provide the information necessary for toolmakers to improve tools, for users to make informed choices about acquiring and using computer forensics tools, and for interested parties to understand the tools' capabilities. Shared test reports and results can be found on the NIST CFTT project webpage. [281]

The CFTT Federated Testing project provides a software suite that is designed to help law enforcement and forensics practitioners with making a copy of the data from seized electronic devices. [282] The federated testing tools allow authorities to run tests on their digital forensics software tools to make sure that it will not fail them when a suspect's personal computer, media, or device arrives in the digital forensics laboratory. Additionally, this software allows different digital forensics laboratories to exchange the results of their tests with each other to share experiences with using a copying method on a specific platform and operating system. The software also includes test reports for tools that perform disk imaging, mobile device acquisitions, and hardware write-blocking.

Through the CFTT project, NIST has also developed Computer Forensic Reference Data Sets (CFReDS) for digital evidence. [283] These reference datasets provide an investigator with documented sets of simulated digital evidence for examination. Investigators can use these datasets to validate software tools, check equipment, train investigators, and develop proficiency tests to support laboratory accreditation activities. NIST recently added reference datasets for drone forensics applications. [284] NIST also administers the National Software Reference Library (NSRL), designed to collect software from various sources and incorporate file profiles into a reference dataset (RDS) of information. [285] The RDS helps law enforcement by alleviating much of the effort involved in determining

[13] All DOD DC3 Tools and Tool Validations are UNCLASSIFIED/For Official Use Only (FOUO) and for U.S. Department of Defense and federal law enforcement and counterintelligence (LE/CI) official use only. To access these tool validations for law enforcement purposes, authorized personnel may submit a request. See the DC3 webpage for more information: https://www.dc3.mil/technical-solutions#tools-validations.

which files are important as evidence on computers or file systems that have been seized as part of criminal investigations. The NSRL recently began adding mobile applications to help filter out known files for mobile device analysis. [286]

1. Quality Assurance and Accreditation

As forensic accrediting bodies began to recognize the need for a DME forensics scope of accreditation, the first public crime laboratory was accredited for digital evidence in 2003. Several public crime laboratories at the federal, state, and local levels are now accredited in DME disciplines. [61, 287, 288] While the DME community is generally supportive of quality assurance implementation activities, participation levels in formal accreditation programs are low, primarily due to continued uncertainty as to the suitability of traditional accreditation standards for DME units. This is compounded by a lack of staffing, accreditation resources, and implementation guidance for smaller DME units. In 2017, the Scientific Working Group on Digital Evidence (SWGDE) published two documents that serve as guidance for digital forensics units that intend to implement a quality management system or pursue accreditation to international standards for forensic testing: the SWGDE Framework of a Quality Management System for Digital and Multimedia Evidence Forensic Science Service Providers, and the SWGDE Overview of the Accreditation Process for Digital and Multimedia Forensic Labs. [289, 290]

NIJ recently sponsored a panel at the 2018 annual conference of the International Association of Chiefs of Police (IACP), in coordination with its Forensic Science and Computer Crimes & Digital Evidence Committees, on "What Every Chief Needs to Know About Quality Management of Forensic Units for Professional Policing." [291] The panel discussed key aspects of forensic quality management systems and approaches to institutionalizing international standards and best practices for the collection, preservation, and analysis of digital evidence. [292] Key aspects of a quality management system include: written procedures for evidence (security, control, and handling); written reports; technical and administrative review of reports and supporting records; testimony monitoring; note taking; technical procedures; training programs; proficiency testing; and corrective and preventive action processes, all of which can serve as a foundation for DME units interested in pursuing accreditation. [130] In order to implement quality management systems, DME units could partner with accredited crime laboratories or establish mutual aid agreements to coordinate accreditation efforts with DME unit partners. Resources are available through the NIJ Coverdell program, which supports the improved quality and timeliness of forensic science services. The Coverdell program recently updated its solicitation language to specifically indicate that digital evidence is included in the purpose area to eliminate backlogs in the analysis of forensic science evidence, and permissible expenses for Coverdell funding also include laboratory equipment, computer hardware and software, accreditation, education, training, and certification (see the sidebar, "The Paul Coverdell Forensic Science Improvement Grants Program").

2. Certification

The 2009 NAS report and the 2004 NIJ report, *Status and Needs of Forensic Science Service Providers*, noted that the lack of standardized training and certification programs, along with limited academic degree programs and continuing education opportunities, needed to be addressed. [30, 60] Since then, the digital forensics community has developed several degree curricula and certification programs in computer security and digital forensics to

address education and professional development needs. The Forensic Science Education Programs Accreditation Commission (FEPAC) began incorporating digital forensics degree requirements in 2009, and two programs have achieved full accreditation in digital forensics (one at the bachelor's level, one at the master's level). [40] Additionally, several organizations have developed certification programs for computer, audio, and video analysis. (See Appendix A in the Views of the Commission: Certification of Forensic Science Practitioners [61].) With the expanding use of DME, law enforcement management and police executives should recognize the need for timely training and continuing education for their DME examiners. While there are several certification and training programs available, there are also several federal programs available to state, local, and tribal digital forensics practitioners, some of which are highlighted in this report (see the sidebars, "Federal Law Enforcement Training Centers (FLETC)"; "Bureau of Justice Assistance Law Enforcement Cyber Center (LECC)"; and "The United States Secret Service National Computer Forensic Institute").

As noted in the 2009 NAS report, recommendations on the utilization of forensic science to address evidence from events that affect homeland security, DME services, innovative DME techniques, and timeliness of DME analysis can enhance the identification and investigation

Bureau of Justice Assistance Law Enforcement Cyber Center (LECC)

Under the direction of the Bureau of Justice Assistance (BJA), the National White Collar Crime Center (NW3C) works in close collaboration with the International Association of Chiefs of Police (IACP) and the Police Executive Research Forum (PERF) to manage and support the Law Enforcement Cyber Center (LECC). The LECC is a web-based information system that provides local, state, and tribal law enforcement officers with critical resources to help them learn about, investigate, and solve cybercrimes; share cyber threat information; and collaborate with regional and federal authorities. The LECC also provides training and resources for prosecutors who focus on the prosecution of cybercrimes.

NW3C also provides a nationwide support system for state, local, tribal, and territorial (SLTT) law enforcement and regulatory agencies involved in the prevention, investigation, and prosecution of high-tech crime. NW3C delivers training and provides analytical technical assistance in digital forensics and high-tech crime investigations. NW3C also conducts original research on all facets of high-tech crime. Over a nearly 40-year history, NW3C has trained over 140,000 personnel; in recent years, it has trained more than 15,000 criminal justice practitioners annually. NW3C currently offers 11 face-to-face and 30 online courses pertaining to digital forensics and high-tech crime investigations. NW3C also uses live, virtual online classrooms to better serve rural and remote jurisdictions. In 2017 and 2018, NW3C successfully developed and delivered content on the emerging high-tech threats that today's criminal justice practitioners face. These subjects include encryption, dark web investigations, virtual currency and block chain investigations, and advanced mobile device acquisition and analysis. Today's SLTT law enforcement and regulatory agencies need training and resources, and NW3C fosters collaboration and information sharing among its many partners within government, the private sector, and academia.

The United States Secret Service National Computer Forensic Institute

In 2008, the United States Secret Service (USSS) established a partnership with the Alabama Office of Prosecution Services, academia, private industry, and law enforcement/legal communities to form the National Computer Forensics Institute (NCFI). NCFI addresses electronic crime cases — which are continually evolving, increasing in number, and affecting communities nationwide — and improves and strengthens the prosecution and adjudication of those cases. NCFI training courses for first responders, basic and advanced examiners, and legal practitioners are offered to state and local law enforcement, prosecutors, and judges through funding from the federal government. Travel, lodging, and equipment for some classes are provided at no cost to attendees or their agencies. All nominations to the institute must be submitted through the local USSS office.

of terrorist activities. [30] There may also be more opportunities for DME examiners to educate and coordinate more closely with the medicolegal death investigation community to advance the use of DME techniques to inform death investigations, particularly in situations where DME may provide critical information for determining the cause and manner of death. Relevant death investigation information (such as suicide notes or text messages) could reside in portable or wearable devices, connected devices in the home or workplace, and even implantable or portable medical devices. [30, 293, 294]

C. Sexual Assault Casework

Needs:

- The ability to process and analyze increasing amounts of forensic evidence related to sexual assault, including both current and previously unsubmitted sexual assault kits (SAKs) as well as other forensic evidence beyond DNA, in order to mitigate and prevent backlogs of evidence in laboratories.
- Realistic stakeholder expectations on issues such as evidence processing times, the ability to obtain usable DNA profiles from items of evidence, the importance of forensic evidence beyond DNA in sexual assault cases, unsubmitted versus backlogged evidence, and the potential to acquire investigative leads.

Challenges:

- Resources and capacity — including infrastructure, laboratory space, personnel, instrumentation/equipment, information technology, and laboratory supplies — are insufficient.
- Previously unsubmitted SAKs in law enforcement custody are a separate and distinct issue from backlogged forensic evidence that has already been submitted to a laboratory for processing and analysis. These issues have vastly different causes, and their solutions require different resources and strategies.
- Forensic evidence beyond DNA may be underutilized in some sexual assault investigations, even though other types of forensic evidence can be fundamental in solving a sexual assault case.
- Recent state and local legislation and policies that mandate auditing, inventorying, testing, and specific turnaround times have increased workload.
- Stored or archived samples from cases where laboratory analysis was previously performed may need to be considered for further examination as new testing technologies become available.

Promising Practices:

- Innovative use of statistical and mathematical models, such as the development of an econometric model for laboratory-specific expected costs of processing SAK backlogs and future submissions for analysis.
- Implementation of standardized SAKs.

- Adoption of the recommendations outlined in the NIJ report, *National Best Practices for Sexual Assault Kits: A Multidisciplinary Approach,* to increase capacities and efficiencies in SAK processing.
- Development of informational resources extending beyond DNA evidence in order to highlight the different types of physical evidence that provide value to a sexual assault investigation beyond a DNA profile, including forensic evidence not in the SAK.
- Recent state legislation and policies that mandate auditing, inventorying, testing, and specific turnaround times, along with commensurate resources to facilitate the implementation of these mandates.
- Utilization of various DOJ resources and funding opportunities, including NIJ and BJA funding to successfully address laboratory efficiency and capacity challenges; inventorying, tracking, and reporting of SAKs; and implementation of multidisciplinary approaches.

A SAK is a collection of evidence gathered from the victim by a medical professional, often a specially trained sexual assault nurse examiner (SANE). The type of evidence collected depends on what occurred during the assault. The contents of a kit vary by jurisdiction, but generally SAKs include swabs, test tubes, microscope slides, and evidence collection envelopes for hairs and fibers.

In contemporary discussions regarding sexual assault investigation, unsubmitted SAKs are often confused with laboratory backlogs of untested SAKs. These are separate and distinct topics. [13] SAKs that remain in the custody of law enforcement agencies and have never been submitted to a laboratory for forensic testing are considered unsubmitted. These SAKs are separate from SAK evidence that has already been submitted to laboratories but has not yet been tested. The Bureau of Justice Statistics defines backlogged evidence as any forensic evidence (including DNA) that has already been submitted to a specialized area of the crime laboratory but has not been examined and reported to the submitting agency within 30 days of submission.

The vast majority of unsubmitted SAKs are in the custody not of forensic laboratories but of the more than 18,000 U.S. law enforcement agencies. Unsubmitted SAKs may also reside in hospitals, medical facilities, and ME/C offices. Additionally, not all laboratories account for SAKs using discrete metrics. Many laboratories, for instance, can track individual pieces of evidence by crime type, such as homicides and sexual assaults. Sexual assault evidence, however, can encompass many more pieces of additional evidence than what is contained in a SAK — weapons, clothing, bedding, digital evidence, and toxicological evidence in cases of drug-facilitated sexual assault. Furthermore, evidence that was included in the SAK at the time of collection may have been processed by the laboratory and stored there as an archived sample, no longer part of the SAK (e.g., serology or microscopy samples). Analysis of stored samples from older cases may need to be considered as new testing technologies become available.

Although the question of how many unsubmitted SAKs are in law enforcement custody frequently arises, there is currently no reliable estimate of the number of unsubmitted SAKs in the country, making addressing the issue particularly complex. [295] NIJ is taking steps

to help address this through the Sexual Assault Forensic Evidence-Inventory, Tracking, and Reporting (SAFE-ITR) program, which helps states and units of local government implement an evidence management program to inventory, track, and report untested and unsubmitted SAKs. [296] Fourteen awards were granted under the SAFE-ITR program from FY 2016 to FY 2018, totaling $6.6 million. [297] The various reasons why SAKs remain unsubmitted include poor evidence tracking, outdated and ineffective investigation practices, lack of resources and personnel, misunderstanding of crime laboratory case acceptance policies, expired statutes of limitations, and lack of understanding among law enforcement personnel about the value of testing SAKs. [13, 298-300] Knowledge of these reasons can be useful in identifying and advocating for targeted resources needed to address this issue.

In response to the identification of thousands of unsubmitted SAKs, many jurisdictions have enacted legislation for statewide inventories and audits of unsubmitted SAKs. Additionally, policies to test all SAKs submitted to the forensic laboratory have been instituted in a number of jurisdictions, mandating maximum turnaround times for analysis that range from 60 days to 6 months depending on the jurisdiction. [301] LSPs noted that such legislation has an impact on their laboratories. In many laboratories, these policies increased workload, exceeding the laboratories' capacity and thus creating backlogs of evidence. One LSP noted that their laboratory experienced a 150% increase in SAK evidence due to new legislation, and another noted an increase of 520% in the number of SAKs submitted to the laboratory. [302] Furthermore, in many jurisdictions, adequate resources to supplement the increase in workload and case submissions have not yet been provided. LSPs also noted that many private laboratories are experiencing the same capacity issues as state and local public forensic laboratories, so relying on private laboratories for overflow may not be a straightforward option for addressing current capacity and backlog challenges. Additionally, the backlog problem will not be eliminated by only considering the untested kits. As backlogs are reduced and evidence is addressed by the justice system, others see that action is being taken. It is expected that this perception will increase the reporting of sexual assaults — which, while a positive shift for the administration of justice, will still add to an already overwhelming SAK workload. (See the sidebar, "Virginia Department of Forensic Science — Sexual Assault Kit (SAKs).")

Virginia Department of Forensic Science — Sexual Assault Kit (SAKs)

Collecting evidence from victims in sexual assault cases is a very important part of the investigative process. But SAKs across the country vary in terms of their contents and documentation. Standardizing kits would allow for consistency in terminology, content, and structure, which would in turn reduce the variability seen in laboratory processes, thus improving efficiencies in SAK analysis. [301] The Virginia Department of Forensic Science (VA DFS) has recognized the need to standardize SAKs, and it now disseminates identical kits to all law enforcement agencies in the state. Additionally, Virginia law enforcement agencies have been trained in evidence collection using those kits. This effort yields consistency in collection and processing.

VA DFS kits are available for pickup at all four VA DFS laboratories (Richmond, Norfolk, Manassas, and Roanoke), or they can be mailed to a recipient when the driving distance to a laboratory exceeds two hours. VA DFS also delivers victim physical evidence recovery kits (PERKs) to local hospitals directly if they are close to a laboratory. Otherwise, law enforcement agencies bring the victim PERKs to the hospitals. The types of kits provided by VA DFS are: victim PERK, suspect PERK, suspect standards kit, and Office of the Chief Medical Examiner PERK. Learn more at http://www.dfs.virginia.gov/field-test-kits/forensic-kits/.

One report noted that in order to create an efficient national system to test SAKs and adjudicate sexual assault cases, laboratories need to invest in hiring, training, and retaining dedicated staff who can collect, process, and analyze SAK evidence. [303] As laboratories' capacity for processing SAKs increases, so does the need to investigate and prosecute the sexual assault investigative leads (i.e., hits from the Combined DNA Index System [CODIS]) that result from testing SAK evidence. [303] Taking a systems-based approach to addressing this increase in evidence is critical. That said, the benefits of testing all SAKs go beyond CODIS hits. Testing SAK evidence helps populate the CODIS database, increasing the likelihood of developing a match at a later time. This improves the justice system's response to sexual assaults, all while sending a positive message to victims, establishing trust between the community and law enforcement, enhancing public safety, holding offenders accountable, and helping to prevent wrongful convictions. [301, 304] As more CODIS hits are developed, more sexual assault victims may be incentivized to report their crimes, and the trauma experienced by the victims can be reduced by the knowledge that their assailant has been properly identified and incarcerated. [304]

It has been reported that law enforcement policies dictating either a submit-all process (e.g., all SAKs must be submitted for testing) or a prioritization process for SAK submissions (e.g., based on time elapsed) have led to significantly higher case clearance rates for sexual assault offenses. [303] Jurisdictions that were highly efficient in both submitting and testing SAKs were more likely to have agencies with submit-all or prioritization policies. Additionally, a cost-benefit analysis suggests that testing all previously unsubmitted SAKs is "quite cost-effective," though a prioritization schedule should still be implemented. [304] An analysis of the societal impact of the DNA database has demonstrated that a return on investment for testing all SAKs can be seen at the national level: Adding one DNA profile leads to social welfare savings as high as $20,000. [305] Further research demonstrates that among various crimes, the deterrence effect — and thus the subsequent societal savings — is highest with violent crimes. [306] Researchers expanded the analysis of the benefits of adding to the DNA database with a concentration on the testing of SAKs and estimated societal gains in excess of $130,000; when compared to the average cost per SAK, DNA analysis yields a return on investment (ROI) of over 8,000%. Further analysis, when updating the probabilities to encompass both backlogged and current cases, demonstrates an ROI of 9,874% to 64,529%, depending on the volume of activity for the laboratory conducting the analysis. [295] Although addressing the current backlog of untested SAKs has these remarkable returns on investment, there are other effects to consider. [304]

In 2013, as part of the reauthorization of the Violence Against Women Act, Congress passed the Sexual Assault Forensic Evidence Reporting (SAFER) Act. The SAFER Act supports: efforts to audit, test, and reduce the backlog of sexual assault cases through increased funding to test and analyze untested DNA evidence and offender samples; funding and auditing standards for all SAKs to account for the backlog of untested DNA samples (including unsubmitted SAKs); and FBI standards for collecting and processing DNA evidence in a timely manner. [307]

Many organizations, including LSPs, have pursued federal resources to address their challenges. The BJA National Sexual Assault Kit Initiative (SAKI) funds jurisdictions to reform their approach to sexual assault cases resulting from evidence found in unsubmitted SAKs (see the sidebar, "Sexual Assault Kit Initiative Training and Technical Assistance (SAKI TTA)"). [298] To learn about the SAKI grantee sites and their progress, see [308].

Additionally, NIJ provides various mechanisms to support this effort. Some of these include the DNA Capacity Enhancement and Backlog Reduction (CEBR) program, the Coverdell program, and the SAFE-ITR program. [96, 297, 309] Often laboratories will engage a number of these programs, each with complementary purposes, to support evidence testing and processing efforts. For instance, the Las Vegas Metropolitan Police Department utilized a number of these resources to reduce their backlog (see the sidebar, "Las Vegas Metropolitan Police Department Coordinated Effort To Reduce Sexual Assault Kit (SAK) Backlog").

A coordinated approach for responding to, and investigating, sexual assaults should address the needs of criminal justice system components as well as those of the victim. Law enforcement agencies, like laboratories, point to insufficient resources as the key barrier to operating at peak technical efficiency. One report found that effective interagency collaboration improves SAK processing. [310] Creating a transparent and collaborative environment can help alleviate the inefficiencies caused by working in individual "silos" and help to avoid unnecessary analysis. Additionally, a multidisciplinary approach should be taken to develop policies pertaining to SAK processing, so that all individual stakeholder considerations are addressed. [303] A multidisciplinary approach provides the opportunity to educate all forensic science service providers, utilize resources appropriately, and create

Las Vegas Metropolitan Police Department Coordinated Effort To Reduce Sexual Assault Kit (SAK) Backlog

The Las Vegas Metropolitan Police Department (LVMPD), like many other jurisdictions, found itself with 5,600 untested SAKs dating back to 1985. The LVMPD committed to testing all of these SAKs. Subsequently, the state of Nevada committed to testing 1,900 SAKs from other law enforcement agencies around the state. This presented a challenge in terms of the resources required not only to test and analyze the SAKs, but also to investigate and prosecute each case, and to provide the necessary support to victims.

As the director of laboratory services for LVMPD began to develop a plan to address the untested SAKs, she also explored multiple funding opportunities and support mechanisms that could address the resource challenges they were facing. As a result, LVMPD utilized funds from the National Institute of Justice's (NIJ) CEBR program to purchase laboratory equipment and supplies and fund employee overtime, in order to enhance their overall testing capabilities. LVMPD also participated in the NIJ-FBI Sexual Assault Kit Partnership program, through which the FBI processed and tested unsubmitted SAKs, free of charge, for law enforcement agencies and public forensic laboratories and entered eligible profiles generated from the DNA analysis into the National DNA Index System. As of August 2018, the SAKs tested through the NIJ-FBI partnership have resulted in more than 100 investigative leads (i.e., Combined DNA Index System hits) for LVMDP. The impact of the LVMPD effort is evident as justice is being brought to victims and more offenders are being held accountable.

In addition to the support NIJ provided for testing the SAKs, the collaboration and coordination between local and state officials were critical to the success of this effort. A sexual assault working group composed of state officials, law enforcement, detectives, prosecutors, victim advocates, and others was assembled by the Office of the Nevada Attorney General. The working group was facilitated through various funding mechanisms, including from NIJ's CEBR program, the Bureau of Justice Assistance SAKI, and the offices of both the New York and Nevada attorneys general. In addition, a grant from the SAFE-ITR program supported Nevada's attorney general in the implementation of an evidence management program to improve coordination and communication between the medical community, law enforcement, laboratories, and the legal community. These actions allowed the different components to pool resources, speak with one voice, and work together to address this issue.

Also important to the success of this effort was the implementation of new standards and procedures to ensure that an accumulation of untested SAKs does not occur again. The success of these efforts was truly the result of an all-stakeholders approach, requiring collaboration between various state and local stakeholders, innovative solutions to resource-related challenges, and adaptation to new ways of doing business.

a collaborative environment where case decisions are informed and educated. For example, the Montana Department of Justice created task forces, or multidisciplinary teams, for this purpose, with membership including representation from law enforcement, prosecutors, SANEs, victim advocates, media, and crime laboratories. [311]

There are a number of resources available for sexual assault stakeholders as they move forward with implementing policies, processes, and best practices and developing multidisciplinary approaches to addressing sexual assault forensic evidence. Some of these resources include:

- NIJ's *National Best Practices for Sexual Assault Kits: A Multidisciplinary Approach* recommends best practices to more effectively process SAKs and provide justice to victims of sexual assault. Recommendations address issues related to transparency and accountability for law enforcement agencies and forensic laboratories in the collection and testing of SAKs, and forensic laboratories' processing of SAKs (see the sidebar, "Oregon State Police Look to NIJ's *National Best Practices for SAKs: A Multidisciplinary Approach* to Tackle SAK Backlogs"). [301]
- The SAKI Training and Technical Assistance (TTA) program, administered by BJA, provides resources and expertise to jurisdictions as they prepare best practices for: collecting and processing forensic evidence; investigating and prosecuting sexual assault cases resulting from evidence from previously unsubmitted SAKs; and supporting sexual assault survivors. (See the sidebar, "Sexual Assault Kit Initiative Training and Technical Assistance"). [298]
- The NIJ FTCoE's Multidisciplinary Glossary on Sexual Assault Violence is a searchable, web-based resource of more than 3,500 terms designed to improve communication across disciplines.
- NIJ's SAK videos cover a range of topics, for example defining a SAK, SAK partnerships, SAK testing, and SAK victim notifications.
- The Rape Kit Action Project provides an overview of the types of provisions states are passing to address SAK backlog concerns and protect victims of sexual assault.

SANEs, who are on the front lines in sexual assault cases, are essential to this multidisciplinary approach. SANEs have received intensive classroom and clinical training and are responsible for the timely collection of thorough, quality evidence. SANEs also ensure the patient's needs are met, increase their level of comfort and cooperation with the legal system, and ultimately enhance public safety. A 12-year analysis demonstrated

Oregon State Police Look to NIJ's *National Best Practices for SAKs: A Multidisciplinary Approach* to Tackle SAK Backlogs

The Oregon State Police faced the task of testing approximately 4,900 unsubmitted sexual assault kits (SAKs) after the passage of Melissa's Law, which eliminated law enforcement discretion for testing SAKs. In order to accomplish this, the police relied heavily on the recommendations in NIJ's *National Best Practices for Sexual Assault Kits: A Multidisciplinary Approach* to increase capacity and efficiency. Some of these actions included establishing clear policies for both evidence submission and prioritization that met the standards outlined by NIJ; use of statistical software; establishing a "high throughput" approach; and incorporating several technical processes to more efficiently and effectively process SAKs. [312] For more information, see the audit highlights at: https://sos.oregon.gov/audits/Documents/2018-16.pdf.

that the implementation of a SANE program resulted in more cases moving through the criminal justice system to higher levels of disposition. [313] In ongoing consultation with law enforcement, SANEs can help strengthen a case through proper collection of quality evidence and thorough documentation of the patient's condition, increasing the likelihood that testing the evidence will garner investigative leads and assist in further developing a case. Law enforcement and prosecutors have confidence in SANEs, and in one study, prosecutors attributed an increase in prosecution rates to the implementation of a SANE program. [313]

Unfortunately, not all jurisdictions have access to SANEs, sexual assault forensic examiners (SAFEs), or sexual assault response teams (SARTs), especially underserved, tribal, and/or remote communities. In an effort to address this gap in service, the DOJ Office for Victims of Crime (OVC) has awarded grants to Pennsylvania State University and the Massachusetts Department of Public Health's SANE program to utilize current web-based and real-time technology. For instance, the Massachusetts SANE program is establishing the National TeleNursing Center (NTC), a trauma-informed and culturally responsive national model for providing telenursing services to survivors of sexual assault in remote communities. It is currently providing services to six hospitals across the United States. The NTC has had 266 patients and 106 consultants, conducted 160 patient exams and over 100 trainings, and secured two guilty pleas with its Rapid DNA Service pilot site (not to be confused with Rapid DNA instruments). [314] Pennsylvania State University is establishing the Sexual Assault Forensic Examination Telehealth Center. The center is a statewide telemedicine solution for improving access to quality forensic sexual assault care and for growing, supporting, and sustaining a SANE-prepared workforce to allow victims of sexual assault to receive high-quality care in rural communities. The reports and evaluations for these projects will be released in the near future, and initiatives such as these will help pave the way for nationwide access to SANE/SAFE resources.

1. Evidence Beyond DNA in Sexual Assault Cases

DNA analysis has had a remarkable impact on the criminal justice system by advancing investigations, identifying suspects, and clearing the innocent. However, other types of forensic evidence may be underutilized in some cases. A reliance on DNA evidence for sexual assault cases may be due in part to the perception that convictions are difficult to obtain without DNA. One report demonstrated that 72% of jurors anticipate seeing DNA in a sexual assault trial, and juries are 33 times more likely to convict when presented with DNA evidence. [300, 315] However, there are many sexual assault cases where DNA is not present, or not of sufficient quality to be eligible for upload to CODIS. There are also cases where the suspect was not a stranger and purports consensual sexual intercourse. In fact, one study reported that in a random sampling of 602 reported rapes, 36% of perpetrators were intimates or family members and 43% were friends or acquaintances. [300] Such cases, if no witnesses are present, will rely on other types of forensic evidence beyond DNA, as the DNA results may not be informative. Similarly, NIJ SAK-related projects revealed that out of more than 7,000 SAKs submitted for DNA testing, only 38% yielded DNA profiles that were of sufficient quality for upload to CODIS. [316] SAK projects in South Dakota and Colorado corroborate this finding. South Dakota's SAK project yielded 254 DNA profiles from the 504 kits tested (just over 50%), and half of the 3,542 kits tested in the Colorado SAK project yielded DNA profiles. [316] Therefore the collection, submission, and analysis of forensic evidence beyond DNA often becomes fundamental to reconstructing or corroborating the events of an assault and establishing fact. NIJ's 2017 publication, *National Best Practices for*

Sexual Assault Kits: A Multidisciplinary Approach, addresses other sources of forensic evidence beyond DNA that can be collected in a sexual assault case (see the sidebar, "Crime Scenes and Other Sources of Evidence"). [301]

Jurisdictions should establish policies for the identification, collection, and preservation of all forensic evidence, not just the evidence collected in the SAK. [301] Additionally, law enforcement, policymakers, and the legal community need to be informed of the value of forensic evidence beyond DNA in a sexual assault case (see the sidebar, "In-Brief Report Series: Beyond DNA — Sexual Assault Investigations").

Crime Scenes and Other Sources of Evidence

Samples collected for the SAK are not the only sources of evidence in sexual assault cases. Jurisdictions should establish policies for the identification, collection, and preservation of all possible evidence, in addition to the SAK, from primary and secondary crime scenes.

Although the focus of this section is to concentrate on the DNA analysis of SAKs collected from sexual assault victims, it is important to consider other forms of evidence collected in these types of cases when indicated. Some of these include but are not limited to the following:

- For drug-facilitated sexual assault (DFSA) cases, controlled substance analysis on powders, pills, syringes, or beverages left at the crime scene and toxicological analysis of urine or liquid blood samples.
- Impression analysis of latent prints on victim's belongings and on weapons, bindings, or other items at the crime scene.
- Digital or other multimedia analysis of phone calls, texts, photos, GPS data, or other items that may help to place the suspect and/or victim at the crime scene.
- Chemical analysis of swabs collected from the victim's body for spermicides or other lubricants.
- Fabric separation analysis of clothing for cuts or tears and comparison to weapons.
- Firearms analysis of clothing for muzzle-to-target distance determination.

Not all forensic laboratories have all forensic discipline capabilities. Jurisdictions should contact their forensic laboratory to confirm its forensic capabilities and submission policies for evidence in sexual assault cases.

Note: See Leadership Institute on Violence Against Women, "National Law Enforcement Leadership Initiative on Violence Against Women." (Alexandria, VA: International Association of Chiefs of Police and Office on Violence Against Women, 2015): http://www.theiacp.org/Leadership-Institute-on-Violence-Against-Women; *Sexual Assault Response Policy and Training Content Guideline*. (Washington, DC: National Institute of Justice, 2003): https://dnn9ciwm8.azurewebsites.net/Portals/0/documents/pdfs/IACPSexualAssaultResponsePolicyandTrainingContentGuidelines.pdf; National Institute of Justice, *Using DNA to Solve Cold Cases, Special Report*. (Washington, DC: National Institute of Justice, 2002), NCJ 194197: https://www.ncjrs.gov/pdffiles1/nij/194197.pdf.

In-Brief Report Series: Beyond DNA — Sexual Assault Investigations

Sexual assault remains pervasive in the United States, with an average of 300,000 cases reported to law enforcement each year. [317] The circumstances and resulting trauma of a sexual assault can pose a challenge to adjudication. For example, witnesses are not always present; the impact of trauma or substances, such as alcohol, may affect the victim's ability to recount details of the incident; and in many circumstances, corroborating evidence could be limited. A DNA profile, while a key piece of evidence, may not necessarily prove probative in every case. [316] The collection, submission, and analysis of physical evidence, therefore, can be effective and necessary when attempting to reconstruct the events of an assault.

The National Institute of Justice's Forensic Technology Center of Excellence developed the *In-Brief Report Series: Beyond DNA — Sexual Assault Investigations*, which highlights the types of physical evidence that provide value to a sexual assault investigation beyond a DNA profile. [318] The series consists of short documents that are designed to provide law enforcement, policymakers, and the legal community with an introduction to each type of physical evidence and the role it may play in sexual assault investigations. This series provides important context that can help key stakeholders in the forensic community ultimately obtain justice for victims.

In-Brief Report Series: Beyond DNA — Sexual Assault Investigations (continued)

There are three reports in this series. They are:

- *The Role of Physical Evidence in Sexual Assault Investigations*: Legal experts from AEquitas (a nonprofit organization focused on developing, evaluating, and refining prosecution practices related to gender-based violence and human trafficking cases) summarize the role that physical injury, toxicology, digital evidence, and other physical evidence types may play in investigations and prosecutions. The report also covers limitations associated with use of physical evidence in sexual assault cases.
- *The Role of Biological Evidence in Sexual Assault Investigations*: Biological evidence, such as semen and saliva, provides details that are important for understanding events that transpired during the sexual assault, even when no CODIS-eligible DNA profile can be generated. This report provides an overview of the role biological evidence may play in sexual assault investigations, including current methods of analyzing the evidence and research currently underway to address technical challenges in evidence collection and testing.
- *The Impact of Toxicological Evidence in Sexual Assault Investigations*: This report illustrates the impact toxicological evidence may play in sexual assault cases, and provides an overview of toxicology analysis techniques and recent research to address technical challenges in collection and analysis.

D. Forensics for Tribal Communities

Needs:

- Further systems-based assessments of the forensic evidence collection and testing needs of tribal communities[14] and a roadmap for forensic evidence analysis.
- Enhanced federal, state, local, and tribal cross-component communication regarding investigations and prosecutions for more efficient testing focus.
- Increased training and resources for investigative and forensic needs.
- Increased guidance for testing prioritization strategies.
- Investigative and forensic partnerships between tribal communities and local, state, and federal agencies to maximize resources and serve as workforce multipliers in a systems-based approach.

Challenges:

- Lack of information on the criminal justice system's forensics interactions with tribal communities.
- Lack of information on the provision, pathways, and policies for forensic services in tribal cases, as well as the current or projected amount of all types of forensic evidence.
- Reliance on external entities to provide forensic services.
- Backlogs in forensic laboratories' requests for analysis and, in some cases, lengthy turnaround times.

[14] The term tribal communities is used broadly to describe those jurisdictions where tribes investigate, prosecute, and detain individuals, as well as those where state or federal partners — with the tribe sharing concurrent jurisdiction — have primary responsibilities for these tasks.

- Lack of consistent and sufficient training on evidence collection and submission practices for all partners involved in providing investigative and forensic services to tribal communities from crime scene to courtroom.
- Formal or informal arrangements tailored to individual tribal community needs, with no one identifiable model or one-size-fits-all strategy.

Promising Practices:

- Forensic services provided by the FBI Laboratory can offer guidance on identifying and addressing basic needs related to evidence collection, analysis, and presentation of forensic testing in tribal cases.
- Efforts have been made to increase data collection and reporting for tribal crimes.
- The Tribal Forensic Healthcare Training Project is addressing the issues of sexual assault in tribal communities, although this project has not yet been evaluated.
- There are many promising training opportunities and partnerships, such as: the Federal Law Enforcement Training Centers (FLETC) Artesia training for tribal law enforcement; the Office on Violence Against Women (OVW) Tribal Special Assistant U.S. Attorney (SAUSA) program; a forthcoming NIJ, OVW, and the National Indian Country Training Initiative training series on the collection, analysis, and presentation of forensic evidence; the NIJ Native American Student Travel Scholarship program; Arizona and South Dakota FBI collaborative partnerships with state laboratories; and task force arrangements and agreements with local crime laboratories.
- To monitor and address drug use in tribal communities, an Indian Health Service policy mandates participation with state prescription drug monitoring programs (PDMPs) for both prescribers and dispensers.

Data on crime and victimization in tribal communities are limited, but studies suggest that victimization rates are much higher for American Indian (AI) and Alaska Native (AN) Americans than for other groups. [319] While there is limited to no comprehensive data on all crimes, investigations, and forensic needs that are equally available for all tribal communities, the BJS Census of State and Local Law Enforcement Agencies, which includes tribal law enforcement agencies, is currently collecting data on the forensic services performed in tribal jurisdictions, such as forensic crime scene investigation, processing of digital evidence, and operation of a forensic crime laboratory. NIJ's AI/AN crime and justice research program gathers much-needed practical, measurable, and descriptive information on the methods and efforts employed by tribal communities in providing victim services, addressing public safety issues, preventing and controlling crime and violence, and strengthening tribal justice systems. [320] Several NIJ reports have reviewed levels of violent crime, including sexual assault and domestic violence, in tribal communities. [321-332]

Recent studies suggest that AI/AN women are 2.5 times more likely than the national average to experience certain violent crimes, such as nonfatal strangulation. [333] Therefore, it is important for criminal justice and social service personnel responding to crimes in tribal communities to be knowledgeable of the types and frequency of abuse perpetrated on the AI/AN population. In addition, all must be mindful of the historical experiences that AI/AN people have suffered at the hands of the federal and state

governments: forced removal from their ancestral homelands, boarding school, slavery, and sexual abuse. [334] Research has found that more than four in five AI/AN women have experienced violence in their lifetime, and the rates of violence for AI/AN men are as high as for women. [319] DOJ has reported that AI/AN women are at least twice as likely to be raped or sexually assaulted as all other races in the United States, with BJS reporting that an AI/AN woman is 3.5 times more likely to be a victim of rape or sexual assault than women of any other race in the United States. [323] AI/AN people living in remote areas may be hours or even days away from health care facilities providing medical forensic exams, which collect evidence related to an assault for use in criminal prosecution. [329]

AI/AN men also have high victimization rates. More than four out of five AI/AN men (81.6%) have experienced violence in their lifetimes. This includes 27.5% of AI/AN men who have experienced sexual violence, 43.2% who have experienced physical violence by an intimate partner, 18.6% who have experienced stalking, and 73% who have experienced psychological aggression by an intimate partner. Overall, more than 1.4 million AI/AN men have experienced violence in their lifetime. [319]

1. The Department of Justice's Work With Federally Recognized Tribes

Currently, there are 573 federally recognized tribes in the United States. [335] According to the Bureau of Indian Affairs (BIA), "[a]pproximately 56.2 million acres are held in trust by the U.S. for various Indian tribes and individuals." [335] Maps developed by the U.S. Census Bureau show the AI/AN areas reported or delineated for the 2010 census and contain graphics that reflect 2010 census data. [336] In addition, the BIA states the following: [335]

> There are approximately 326 Indian land areas in the U.S. administered as federal Indian reservations (i.e., reservations, pueblos, rancherias, missions, villages, communities, etc.). The largest [such land area] is the 16 million-acre Navajo Nation Reservation located in Arizona, New Mexico, and Utah. The smallest is a 1.32-acre parcel in California where the Pit River Tribe's cemetery is located. Many of the smaller reservations are less than 1,000 acres.

Approximately 5.2 million people in the United States identify as Native American, "either alone or in combination with one or more other races," per the 2010 census. [337] And of this group, 2.9 million, or 0.9% of the total U.S. population, identify only as Native American. [337] In 2010, more than 1.1 million Native Americans resided on tribal land. [337]

The two main federal statutes governing federal criminal jurisdiction in Indian Country are 18 U.S.C. § 1152 and § 1153. [338, 339] Section 1153, known as the Major Crimes Act, gives the federal government jurisdiction to prosecute certain enumerated offenses, such as murder, manslaughter, aggravated sexual abuse, aggravated assault, and child sexual abuse, when they are committed by Indians in Indian Country. [339] Section 1152, known as the General Crimes Act, gives the federal government exclusive jurisdiction to prosecute all crimes committed by non-Indians against Indian victims in Indian Country. [338] Section 1152 also grants the federal government jurisdiction to prosecute minor crimes by Indians against non-Indians, although that jurisdiction is shared with tribes, and provides that the federal government may not prosecute an Indian who has been punished by the local tribe. [338]

To protect tribal self-government, Section 1152 specifically excludes minor crimes involving Indians, when the crimes fall under exclusive tribal jurisdiction. [338] The federal government also has jurisdiction to prosecute federal crimes of general application, such as drug and financial crimes, when they occur in Indian Country, unless a specific treaty or statutory provision provides otherwise. [338] On a limited number of reservations, the federal criminal responsibilities under Sections 1152 and 1153 have been ceded to the states under Public Law 280 or other federal laws. [338, 339]

The United States Constitution, treaties, federal statutes, executive orders, and court decisions establish and define the unique legal and political relationship that exists between the United States and Indian tribes. DOJ recognizes the United States' unique legal relationship with federally recognized Indian tribes. In January 2010, the deputy attorney general (DAG) sent a memorandum to all U.S. Attorneys' Offices (USAOs) with Indian Country responsibility and directed them to engage annually, in coordination with their law enforcement partners, in consultation with the tribes in their districts. Following such consultation, every USAO was instructed to develop an operational plan addressing public safety in Indian Country; this document is to be reviewed and updated annually. [340]

Per the DAG memo, "the subject matter of each district's plan will depend on the legal status of the tribes in that district (i.e., whether the jurisdiction is Public Law 280, non-Public Law 280, or partial Public Law 280) as well as the unique characteristics and challenges confronting those tribal nations." [340] The following elements were suggested by the memo for inclusion in a USAO's operational plans: a plan to develop and foster an ongoing government-to-government relationship; a plan to improve communications with each tribe, including the timely transmittal of charging decisions to tribal law enforcement, where appropriate; a plan to initiate cross-deputization agreements, Special Law Enforcement Commission training, and a Tribal SAUSA program, where appropriate; and a plan to establish training for USAO staff and all relevant criminal justice personnel on issues related to Indian Country criminal jurisdiction and legal issues. Every USAO or FBI employee assigned to work in Indian Country should be familiar with and have readily available a copy of their district's most current operational plan.

Improving public safety and the fair administration of justice in Indian Country is a top priority for DOJ. In fact, in December 2014, the attorney general issued guidelines stating principles for working with federally recognized Indian tribes. [341] These guidelines apply to all DOJ personnel working in Indian Country. The overarching principles as directed by the attorney general are the following:

- DOJ honors and strives to act in accordance with the general trust relationship between the United States and tribes.
- DOJ is committed to furthering the government-to-government relationship with each tribe, which forms the heart of its federal Indian policy.
- DOJ respects and supports tribes' authority to exercise their inherent sovereign powers, including powers over both their citizens and their territory.
- DOJ promotes and pursues the objectives of the United Nations Declaration on the Rights of Indigenous Peoples.

- DOJ is committed to tribal self-determination, tribal autonomy, tribal nation-building, and the long-term goal of maximizing tribal control over governmental institutions in tribal communities, because tribal problems generally are best addressed by tribal solutions, including solutions informed by tribal traditions and customs. [341]

The attorney general's guidelines for working with federally recognized tribes also address DOJ efforts concerning law enforcement and the administration of justice in tribal communities, which are priorities for USAOs and the FBI:

- DOJ is committed to helping protect all Native Americans from violence, takes seriously its role in enforcing federal criminal laws that apply in Indian Country, and recognizes that, absent DOJ action, some serious crimes might go unaddressed.
- DOJ prioritizes helping protect Native American women and children from violence and exposure to violence, and works with tribes to hold perpetrators accountable, protect victims, and reduce the incidence of domestic violence, sexual assault, and child abuse and neglect in tribal communities. [341]

It is against this backdrop that the men and women involved in the justice system are assigned to work in tribal communities, and many of the cases they work involve violent crime. The collection and analysis of forensic evidence collected at crime scenes is a critical piece of the systems-based criminal justice response to crime in tribal communities.

2. Landscape of Service Provision to Tribal Communities

The principal health care provider for approximately 1.9 million American Indians across 35 states is the Indian Health Service (IHS) in the Department of Health and Human Services (HHS), which funds 45 IHS and tribally operated hospitals. In a 2011 report developed in response to the Tribal Law and Order Act of 2010, the Government Accountability Office (GAO) determined that 34 of these facilities are in areas characterized as "remote," and 11 are in urban areas. [328] GAO survey results revealed severe gaps in IHS response to the need for medical forensic services for sexual assault, and there was also a lack of training and services found for both sexual assault and family violence cases. [328] Stakeholders, when discussing sexual assaults, also mentioned challenges related to these cases, including a concern over the number of offenses not reported to law enforcement. Even in a jurisdiction with an IHS medical facility, victims in small communities may not feel comfortable going to the local hospital for fear of people knowing that they sought medical attention or that they had been victimized. Instead, some victims may travel hours to reach medical care. The nature of small communities coupled with either the lack of access to a SART or SANE can lead to a lack of reporting. Another concern addressed during stakeholder conversations was the preservation and storage of anonymous SAKs. Many hospitals have a 30-day disposal policy,[15] yet tribal police or forensic agencies also struggle to store SAKs related to anonymous case processing, due to space and backlog concerns. Though different agencies may have their own policies, individual IHS facilities must follow national IHS policy, which has neither a time limit on submission and processing of SAKs, nor an existing policy to guide the tracking of anonymous kits.

[15] This includes hospitals that are not on tribal lands but serve AI/AN people, which then fall outside of the IHS guidelines on SAKs.

Tribal justice and the provision of services involve a wide and varied constellation of federal, state, local, and tribal agencies working together to address crime in tribal communities. Tribal communities include both Public Law 280 (PL 280) tribes and non-PL 280 tribes.[16] In PL 280 tribes, crimes that occur on tribal land generally fall under state jurisdiction. In non-PL 280 tribes, criminal jurisdiction is generally concurrent between federal and tribal governments. In addition, non-PL 280 tribes may have exclusive jurisdiction over certain types of crime occurring on tribal land in non-PL 280 tribes, and have concurrent jurisdiction with both the states and the federal government in other circumstances. There are many caveats and exceptions to these general rules, and local jurisdictions should be consulted for specifics on how crimes are handled in their jurisdictions. Of note, two-thirds of all federally recognized tribes are located in PL-280 states, specifically Alaska and California. The PL280 and Strategic Application International websites, developed through BJA's Community Oriented Policing Services training program, provide more background information on this topic. [342-344]

While these different jurisdictional matrices suggest that a future, systems-based needs assessment of these particular providers and clients would be beneficial, stakeholders acknowledged that jurisdictional relationships can sometimes generate tensions. However, positive conversations with stakeholders helped identify promising initiatives and training opportunities. OVC established the National Coordination Committee on the AI/AN SANE-SART, which prepared a report with specific recommendations to the attorney general in an effort to foster better collaboration among intersecting government agencies at the local level. These recommendations included: directing USAOs in each district with Indian Country jurisdiction to develop district-specific, written guidelines for federal response to sexual violence in Indian Country; [345] inclusion of outreach and training efforts, as well as collaborations, related to sexual assault in performance appraisals of Assistant United States Attorneys (AUSAs); [345] promoting investigation of sexual violence reports, use of child/adolescent interviews for federal prosecution, and guidelines on sexual assault medical forensic examinations and SAKs; and directing USAOs and the FBI to assign appropriate staff to SARTs and multidisciplinary teams (MDTs).

The attorney general directed U.S. Attorneys with Indian Country jurisdiction to implement two of these recommendations as follows: 1) All U.S. Attorneys with jurisdiction to prosecute crimes in Indian Country shall meet with federal partners (FBI, BIA, and IHS) and tribal partners to develop written sexual violence guidelines that detail the specific responsibilities of each federal partner by August 12, 2016. U.S. Attorneys shall implement those guidelines by September 9, 2016. U.S. Attorneys with Indian Country jurisdiction but without the authority to prosecute crimes shall discuss federal sexual violence response with their tribal partners and federal partners as appropriate during annual consultations. 2) U.S. Attorneys with Indian Country jurisdiction shall ensure that performance appraisals of AUSAs with Indian Country responsibilities include consideration of relevant factors such as AUSA outreach to tribal leaders and victims; training received or delivered; successful and

[16] Generally, in PL 280 tribes the state is responsible for the investigation, prosecution, and detention needs of tribal communities, while in non-PL 280 tribes the federal government assumes these responsibilities. In both PL 280 and non-PL 280 states, the tribe maintains concurrent jurisdiction. There are many caveats and exceptions associated with PL 280 and non-PL 280 determinations. It is recommended that agencies seeking to work with tribal communities contact the tribe directly to determine their status related to PL 280. Additional information can be found at Public Law 280, USC Title 25, Chapter 15, Subchapter III § 1321.

innovative collaboration with federal and tribal partners; and specific efforts to enhance a victim-centered prosecution process, in addition to any other performance metrics currently used. [345] Furthermore, in July 2010, the Executive Office for United States Attorneys (EOUSA) launched the National Indian Country Training Initiative (NICTI) to ensure that DOJ prosecutors, as well as state and tribal criminal justice personnel, receive the training and support needed to address the particular challenges relevant to Indian Country prosecutions. (See the sidebar, "Tribal Resources.")

Training for law enforcement working in Indian Country is also readily available through the Indian Police Academy and the FLETC located in Artesia, New Mexico (see the sidebar, "Federal Law Enforcement Training Centers (FLETC)," for more information). FLETC receives dedicated appropriations to train tribal, state, and local law enforcement personnel, who only need to pay for travel (tuition, lodging, and per diem are provided at no cost). FLETC provides training in the field and electronically. Additionally, FLETC students frequently get to keep the equipment from the trainings when they leave, so they can immediately implement what they have learned when they return to work. Stakeholders

Tribal Resources

OVC Tribal Multimedia Resources

In partnership with the Department of Justice (DOJ) National Indian Country Training Initiative (NICTI), the Office for Victims of Crime (OVC) and the Office on Violence Against Women (OVW) developed an educational video series for federal, state, local, and tribal victim service providers, criminal justice professionals, and others who work with Alaska Native victims of domestic violence, sexual assault, and human trafficking. This series of videos advocates for a multidisciplinary, collaborative approach in responding to violence committed against Alaska Natives. It also provides resources and tools for, and heightens awareness about, responding to such situations in a culturally sensitive manner. Watch the videos at https://ovc.gov/library/healing-journey.html.

Tribal Forensic Healthcare Training Project

Through the Tribal Forensic Healthcare Training Project, the Indian Health Service funds the International Association of Forensic Nurses (IAFN) to deliver training related to the identification, collection, and preservation of medical forensic evidence obtained during the treatment of victims of sexual and domestic violence. These trainings allow medical professionals to acquire and maintain the knowledge, skills, and competent clinical forensic practice needed to improve the response to domestic and sexual violence in hospitals, health clinics, and health stations within the Indian health system. Learn more at http://www.tribalforensichealthcare.org.

National Indian Country Training Initiative

The NICTI is based at the National Advocacy Center (NAC) in Columbia, South Carolina. This effort ensures that DOJ prosecutors, as well as state and tribal criminal justice personnel, receive the training and support needed to address the particular challenges of Indian Country prosecutions. Since its inception, the NICTI has delivered well over 100 residential training courses at the NAC and in the field. In addition, the NICTI Coordinator has delivered hundreds of presentations for other federal agencies, tribes, and tribal organizations held around the country. The NICTI has reached all United States Attorneys' Offices with Indian Country responsibility and over 300 tribal, federal, and state agencies. In addition to live training, the NICTI issues written publications and serves as faculty for other federal agency trainings, webinars, tribally hosted conferences, and technical assistance providers serving Indian Country. Importantly, DOJ's Office of Legal Education covers the costs of travel and lodging for tribal attendees at classes sponsored by the NICTI. This allows many tribal criminal justice and social service professionals to receive cutting edge training from national experts at no cost to the student or tribe. The NICTI, in collaboration with the National Institute of Justice and OVW and with assistance from an ad hoc steering committee organized by the NICTI, is currently developing a video training program on the collection, analysis, and presentation of forensic evidence in court.

explained that training courses, such as those related to crime scene management, evidence collection, and preparing for courtroom testimony, are often filled with a mix of personnel from the various agencies responsible for these tasks in tribal areas. Other, smaller agencies, such as local tribal police, may have hiring policies that require personnel to have been sworn elsewhere first in an effort to reduce training costs. Stakeholders emphasized that transparent leadership, including robust policies and strong hiring and training standards, is required not only to make partnerships with other agencies work, but also to foster community trust.

Another area of discussion with stakeholders identified that the lack of data and crime metrics for tribal jurisdictions presents a significant challenge to accurately assessing the needs of these communities. For example, it should be acknowledged that "there's virtually no record of exactly how many indigenous women are currently missing," although not all missing persons may have been the victim of a crime. [326] This unknown factor reflects a larger issue: Due to reporting practices and other factors, the number of unreported or unknown missing adults in tribal communities is an area of concern. Given recent media attention focused on this issue, agencies and partners involved in investigating these disappearances are honing their efforts. For example, the National Missing and Unidentified Persons System (NamUs) (see the sidebar, "National Missing and Unidentified Persons System (NamUs)") has added new data fields in an effort to increase the collection of data and case information regarding the number of missing and murdered AI/AN men and woman. These new data fields will help gain relevant information related to the investigation of missing and/or unidentified indigenous persons cases, with the goal of resolving more cases and increasing communication across tribal, local, state, and federal jurisdictions. Many of these new data fields require an answer to complete case submission. [346] The Bureau of Indian Affairs, Office of Justice Services, has made it an operational priority to estimate the number of missing persons cases, acknowledging that some of these missing individuals may be victims of other crimes, such as homicide or human trafficking, that come to its attention. [347-349] If the true extent of crime and victimization is unknown, due in part to low reporting rates and other unknown crime impacts, then the true needs of forensic service providers may also be unknown and underestimated.

In spite of these unknowns, stakeholders found that continued trust and developing relationships are critical to the provision of efficient and effective service through partnerships between the various enforcement agencies, forensic and victim service providers, and community clients involved. These collaborative partnerships can extend to many areas of forensic needs: addressing potential pipeline[17] impacts through the NIJ Native Student Travel Scholarship Program: Connecting Science to Crime and Justice unique arrangements to prosecute offenses from tribal areas, and others. [350] Some tribal jurisdictions face many of the same challenges that rural jurisdictions face related to resources, but with more constrictions and economic impediments, such as having to travel a great distance to forensic services and service providers, having few law enforcement and other service providers in the immediate community, and budgetary constraints. Tribal jurisdictions may need to form cooperative agreements with other agencies, particularly at the state or federal level.

[17] The term pipeline, in this needs assessment, refers to the number of potential forensic scientists and forensic service providers that are in training to enter, or are in the hiring and training process for, these career fields. For more information and context, see the Personnel section of this report, specifically the Pipeline subsection.

FBI agents, BIA officers, state and local police, and tribal police must work together to provide enforcement and investigative services to tribal communities. While state and federal governments have a responsibility to provide these services, based on the jurisdictional arrangement, more formal processes and policies are needed to facilitate timely access to forensic services and avoid analysis bottlenecks. Some jurisdictions enter into cross-deputization agreements between law enforcement officers across federal, state, local, and tribal jurisdictions or allow officers from other jurisdictions to function as auxiliary officers. Generally, service provision arrangements can be complicated, but in keeping with the goals of community-oriented policing, it is not expected that there will be a one-size-fits-all model that can be adapted throughout Indian Country. Instead, partners should come together to develop and maintain an individualized community response and proactively evaluate what works, what does not work, and which solutions can address workflow challenges.[18] Stakeholders recognize that cooperative agreements may be necessary, given limited personnel and resources, and that joint ventures such as task forces are a particularly useful way to provide tribes with greater access to additional state resources and reduce barriers to accessing forensic testing services.

The FBI Laboratory provides forensic services for evidence collected from crimes occurring in Indian Country, including evidence from serious crimes like sexual assaults and homicides, as well as toxicology evidence. Stakeholders noted that state and local crime laboratories also provide services based on established local relationships, which may or may not be formal agreements or required by state or local statute. Formal cooperative arrangements are also exemplified in the agreements utilized in Arizona and South Dakota, where the FBI handles major felonies in Indian Country. The FBI has established agreements with the state crime laboratories to process the evidence from their cases. These agreements, whereby the state crime laboratory provides forensic services through an annual flat fee, have been in effect since at least 2010 in South Dakota, and since 2016 in Arizona. The fees provide a steady source of revenue for these facilities, and the agreement also allows the law enforcement agencies serving these areas to receive forensic services despite their limited budgets, which would not allow for per-test or per-service payment. The agreement also allows for reduced turnaround time and facilitates the presentation of evidence in court, as state experts can testify more readily and for less cost. Further, these arrangements with state laboratories aid in faster turnaround times and facilitate working relationships between local agencies and the FBI to avoid evidence delays and potential backlogs at the federal laboratories. One tribe in California, the Sycuan Band of the Kumeyaay Nation, has developed an arrangement with its local crime laboratory to gain access to and facilitate the testing of forensic evidence.

Stakeholders noted that accessing ME/C services and referring cases for prosecution were often not a problem, and services are sometimes facilitated by the FBI or BIA. However, tensions can arise during the provision of death investigation services. ME/C offices must be familiar with and respectful of the cultural and religious beliefs of the tribes in their area when handling cases (see the sidebar, "Medical Examiner/Coroner Tribal Coordination").

Some ME/C offices have made building accommodations to allow for specific rituals. ME/C offices should know or inquire about any special rituals or practices that families may want to observe. Tribes have a diversity of beliefs and practices, and ME/C offices can promote the communication needed to facilitate successful death investigations by building respectful, mutually trusting relationships with tribal communities.

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[18] For more information on workflow challenges, see the Workload section of this needs assessment.

Medical Examiner/Coroner Tribal Coordination

Some tribes have cultural and religious beliefs which require special rituals or practices when a tribal member passes away that the tribes would like the medical examiner/coroner (ME/C) offices to honor. ME/C offices are not always equipped to support these rituals, and they may not always know what rituals are required by the surviving family members.

There are some ME/C offices that have made strides towards creating a respectful and supportive relationship with tribal communities. ME/C offices can create a mutually trusting relationship with the community by fostering communication and respect. For example, in North Dakota, the foundation of such a relationship was laid when the state university supported educational work with Native American students in the medical, health science, and graduate/STEM programs. This educational work created a known and trusted environment for the tribal communities prior to the provision of forensic science services. Relationships can be strengthened by routinely inquiring whether there are any special rituals or practices the tribe or the decedent's relatives would like the ME/C office to honor, or by working together to identify ways of designing the morgue to accommodate different and diverse groups. Having an open and honest dialogue is essential, especially since individual tribal members and families are as diverse in beliefs and requests as any other community.

Stakeholders were also asked about the impact of the opioid crisis in tribal jurisdictions.[19] Some representatives noted that heroin was "almost gone" from their jurisdictions until the past few years, while others noted that there has been an increase in heroin use. Specific drug trends may be region specific. The CDC noted that national statistics on the opioid epidemic, which report that overdose mortality rates are significantly higher among whites than among the AI/AN population, are not reflective of regional prevalence, disparities, and trends. The CDC recently examined drug overdose data of AI/AN people reported in Washington state and found that, while AI/AN people and whites had similar overdose mortality rates from 1999 to 2001, subsequent overdose rates among the AI/AN population from 2013 to 2015 increased at a faster rate than did those among whites for total drug overdose mortality (2.7 times faster), opioid-involved overdose mortality (2.7 times faster), and heroin-involved overdose mortality (4.1 times faster). [351] Washington death certificates that were not corrected for misclassification of AI/AN race underestimated drug overdose mortality rates among AI/AN people by approximately 40%. The National Drug Early Warning System (NDEWS) is conducting 6- to 8-month, community-based HotSpot studies with local scientists and practitioners to examine drug outbreaks and increases in the harmful consequences of drug misuse. A HotSpot study currently underway in Minnesota is examining the feasibility of developing and implementing a model for fatality reviews of opioid overdose deaths with a rural northern Minnesota tribe. Local scientists will work with the tribe to develop a research model and conduct approximately 12 fatality reviews. The report will be available at the NDEWS website. (See the sidebar, "National Drug Early Warning System (NDEWS) — Resources for Crime Laboratories and Medical Examiner/Coroner Offices.")

In addition to the focus on heroin and other opioids, tribal stakeholders also identified more common substance abuse concerns related to alcohol, methamphetamines, and prescription medications. With regard to prescription medications, the implementation of DEA National Prescription Drug Take Back Day events — where community members can hand over old or unused medications for destruction — have shown preliminary promising results as an example of collaborative efforts for drug use reduction and prevention in

[19] For more information on the opioid crisis and the substances included in this discussion, see the Opioid Crisis and Emerging Drug Threats section of this needs assessment.

tribal communities. [352] Additionally, PDMPs are used by pharmacists and prescribers to monitor and deter prescription medication misuse, abuse, addiction, and diversion. IHS policy now mandates participation with state PDMPs for both prescribers and dispensers. States with tribal communities should consider giving ME/C offices access to the PDMPs as well as interstate data-sharing measures, to strengthen drug death investigations in Indian Country (see the sidebar, "Prescription Drug Monitoring Programs"). [353]

E. Human Factors

Needs:

- Training in and resources for quality assurance techniques to limit the impact of human factors.
- Dedicated laboratory staff to identify and implement laboratory- and systems-based approaches to addressing human factors.

Challenges:

- Limited personnel available to function as dedicated case managers.
- Limited research demonstrating the impact of human factors in a forensic laboratory environment and showing where interventions could be appropriate.
- Increasing workloads, backlogs, and stressful work environments.

Promising Practices:

- Systems-based approaches to limit task irrelevant information.
- Implementation of standard protocols for documentation of examinations.
- Routine case reviews among laboratory staff, apart from analysts, to verify conclusions.

The 2009 NAS report called for research programs on the effects of human factors in forensic practice. [30] Human factors research is a multidisciplinary field that examines ways in which human performance (e.g., the judgments of experts) can be influenced by cognitive, perceptual, organizational, social, and cultural factors and other human tendencies. [354] Whenever humans make decisions based on individual judgment, they may be vulnerable to psychological and cognitive influences that can lead to inconsistencies in decision-making. [355-358] Since the publication of the 2009 NAS report, the forensic science community has examined human factors related to topics including latent fingerprint analysis and document examination. [358-363] NIJ and NIST are also currently partnering to examine human factors in DNA mixture interpretation and toolmark examinations. If research demonstrates the potential for inconsistent case outcomes, this should lead to the development of standard operating procedures that minimize potential bias and sources of human error.

Since the NAS report, the forensic science practitioner community has taken many positive steps to address potential issues. The Organization of Scientific Area Committees (OSAC), launched in 2014, works to strengthen the nation's use of forensic science by facilitating the development of technically sound forensic science standards and by promoting the

adoption of those standards by the forensic science community. OSAC is administered by NIST, and the great majority of its more than 550 members and 250 affiliates are from other government agencies, academic institutions, and the private sector. OSAC also has three resource committees. One of these, the Human Factors Committee, provides guidance throughout OSAC, for the 25 specific forensic disciplines represented, on the influence of systems design on human performance and on ways to mitigate errors in complex tasks. The FTCoE is developing the forthcoming Human Factors Sourcebook (see the sidebar, "FTCoE Human Factors Sourcebook") along with other tools that will maximize consistency and quality in the forensic workplace. Overall, the forensic science community has not only acknowledged the potential issues of human factors, but has led the process to discuss these concerns and develop solutions to advance the field. [63, 364-366]

FTCoE Human Factors Sourcebook

The National Institute of Justice (NIJ) directed the Forensic Technology Center of Excellence (FTCoE) to develop a sourcebook on human factors in forensic science to advance the understanding and adoption of insights from cognitive psychology into forensic practice. The sourcebook will provide insights to allow forensic science leaders and professionals to solve problems, whether they arise at the individual laboratory level or at the national level for policy and standards-setting.

The sourcebook will be designed to serve a wide range of forensic science stakeholders in three primary ways: 1) to guide forensic laboratories to consider how human factors considerations can improve the practice of forensic science; 2) to establish an understanding of the state of knowledge of human factors as applied to forensic practice; and 3) to inform NIJ and others in the research community about research that may elucidate key issues in human factors. The sourcebook will cover a diverse array of subjects related to challenges faced by forensic science organizations and practitioners, including:

- Personnel selection and assessment
- Learning from errors
- Accumulating, integrating, and assessing information
- Laboratory culture
- Communicating forensic evidence

F. Mass Disaster and Critical Incident Preparedness and Response

Needs:

- Increased coordination, training, and regular communications with public safety and public health agencies for preparedness planning and response operations.
- Resources and equipment to respond during and after an event.
- Training for personnel protection at the scene and safe handling of evidence exposed to hazardous materials.

Challenges:

- Routine forensic casework does not stop during or after a mass disaster or critical incident.
- Mass disasters and critical incidents may affect forensic operations, requiring surge support and robust plans for continuity of operations.

Promising Practices:

- Joint exercises and cross-training with public safety and public health agencies that provide preparedness, incident management, and response functions.
- Forensic science personnel who possess foundational knowledge for scene and evidence processing and may also participate in the response to mass disaster events.
- Use of the Department of Homeland Security's (DHS) National Incident Management System as a framework for forensic preparedness and response operations.

The 2009 NAS report recommended that forensic scientists and crime scene investigators should be prepared for their potential roles in managing and analyzing evidence from events that affect homeland security, both to maximize evidentiary value and promote the safety of forensic personnel. [30] The report went on to acknowledge that the ME/C community could be perceived as a "geographically distributed and rapidly deployable corps" that can enhance federal efforts to monitor emerging public health threats or respond to critical incidents. Several federal agencies and state/local task forces — e.g., DHS, Federal Emergency Management Agency (FEMA), FBI, CDC, and National Guard Civil Support Teams — may participate in the response to mass disasters and critical incidents, including events involving chemical, biological, radiological, nuclear, and explosive materials. State and local forensic laboratories and ME/C offices may also be called upon to support these operations. State and local forensic resources can provide initial assets; state and local forensic personnel can serve as forensic first responders or provide surge capacity to address mass disaster or critical incident events and supplement further investigations. Forensic and ME/C examinations can also aid the detection and prevention of potential terrorist activities through awareness of emerging threats and mortality surveillance, similar to the sentinel laboratory networks established to identify and characterize public health threats. [9, 215, 246, 367] The forensic science community identified the need for increased support to crime laboratories, ME/C offices, and other crime/disaster scene first responders for mass disasters and critical incidents that might result in mass casualties — including support for training, equipment, and coordination activities, as well as specific training for the safe handling of evidence (see the sidebar, "OVC Mass Violence and Terrorism Toolkit"). [60]

OVC Mass Violence and Terrorism Toolkit

Previous experiences with mass violence and terrorism indicate that advanced planning, preparation, and multidisciplinary partnerships better prepare communities to respond to victims in the most timely, effective, and compassionate manner possible. In recognition of this need, the Office for Victims of Crime (OVC), in coordination with the FBI's Office for Victim Assistance and the Department of Justice's Office of Justice for Victims of Overseas Terrorism, has developed a toolkit that provides victim service providers with the framework, strategies, and resources to conduct planning and preparation ahead of an incident and mitigate the impact of future acts on victims. Additionally, this toolkit provides resources to help communities respond to victims even if they have not planned for an incident in advance.

There are three sections to the toolkit: Partnerships and Planning, Response and Recovery, and Tools. The Partnerships and Planning section reviews how to create and maintain partnerships, address resource gaps, and develop victim assistance protocols. The Response and Recovery section covers how to use the protocols after an incident of mass violence or terrorism. The Tools section includes checklists, template samples, a glossary, and a compendium of victim assistance resources.

Access the toolkit at https://www.ovc.gov/pubs/mvt-toolkit/.

Further engagement between public safety and public health agencies, forensic laboratories, and ME/C offices can determine how forensic assets may best be incorporated into preparedness and response planning to ensure operational readiness to address all potential hazards. Formalized partnerships and participation in both joint operations exercises and tabletop exercises can strengthen levels of preparedness and identify key roles in managing scenes and physical evidence. The DHS National Incident Management System (NIMS) provides guidance to prevent, protect against, mitigate, respond to, and recover from incidents, and the NIMS *Intelligence/Investigations Function Guidance and Field Operations Guide* provides specific information for the roles and processes assigned to the Forensic, Mass Fatality Management, and Missing Persons Groups. [368, 369] FEMA also provides training for NIMS and Incident Command System operations. [370, 371]

Additional resources and equipment may be needed to prepare for and implement forensic response functions during and after an event, and training is needed to adequately protect personnel at the scene and to safely handle evidence exposed to hazardous materials. While forensic science personnel possess foundational knowledge in these areas, specialized training may be considered, such as the types of training typically received for processing clandestine drug laboratories and hazardous materials environments. [372, 373] As forensic laboratories implement new technologies, the forensic and homeland security communities may consider cross-cutting applications, such as Rapid DNA instrumentation for disaster victim identification. However, the instrumentation, supplies, and consumables can be costly, which is a barrier to implementation. Laboratories and ME/C offices should consider funding opportunities to support these goals. Under the FEMA Homeland Security Grant program, forensic laboratories and ME/C offices should consider partnering with agencies that apply for funding that strengthens state and local capabilities to prevent, protect against, mitigate, respond to, and recover from potential terrorist attacks and other hazards. (See the sidebar, "FEMA Homeland Security Grant Program.")

FEMA Homeland Security Grant Program

The Federal Emergency Management Agency's (FEMA) State Homeland Security Program (SHSP) and Urban Area Security Initiative (UASI) are administered through the Homeland Security Grant Program (HSGP) and provide funding to states, territories, and urban areas to prevent, protect against, mitigate, respond to, and recover from potential terrorist attacks and other hazards. The HSGP plays an important role in the implementation of the National Preparedness System by supporting the building, sustainment, and delivery of core capabilities that strengthen national preparedness and resilience through funding a range of investments including planning activities, organizational resources, equipment, training, exercises, management, and administration. FEMA uses 32 core capabilities to inform funding allocations, and the total HSGP funding available in FY 2018 included $402 million under the SHSP and $580 million under the UASI. More information on the HSGP, including notice of funding opportunities and supporting information, can be found on the FEMA HSGP webpage.

The SHSP and UASI prioritize grant funding based on the capability targets and gaps identified through the annual Threat and Hazard Identification and Risk Assessment (THIRA) and Stakeholder Preparedness Review (SPR) process, with emphasis on whole-community preparedness. The THIRA helps communities understand their risks and determine the level of capability they need in order to address those risks. The SPR is an annual capability self-assessment that helps jurisdictions identify capability gaps and prioritize investments required to reach the targets set in their THIRA. Using the SPR to prioritize funding requests creates a stronger investment justification. State Administering Agencies (SAAs)[1] can utilize up to 20% of the SHSP funds for state agencies, and the SAA must pass through at least 80% of the funds awarded under

[1] FEMA SAA points of contact for the Homeland Security Grant program may be different from the DOJ Office of Justice Programs' SAA contacts for grant programs such as the National Institute of Justice Paul Coverdell Forensic Science Improvement Grants program and the Bureau of Justice Assistance's Justice Assistance Grant program. For additional information and distinctions, refer to https://www.fema.gov/media-library/assets/documents/28689 and https://ojp.gov/saa/.

FEMA Homeland Security Grant Program (continued)

SHSP to local or tribal units of government, which may include city, county, or local groups or subrecipients. [129] SHSP and UASI participants are also required to ensure that a certain portion of the funds is dedicated toward law enforcement terrorism prevention activities. HSGP recipients are also required to implement National Incident Management System-type resources for sharing resources, coordinating and managing incidents, and communicating information.

Examples of allowable uses for SHSP and UASI grant funds include:

- Planning — developing or enhancing plans, protocols, and assessments (staff/contractors, travel, supplies)
- Organizational activities — employing intelligence analysts, operational overtime
- Equipment — HSGP lists 21 allowable prevention, protection, mitigation, response, and recovery equipment categories and equipment standards on its Authorized Equipment List, such as:
  - Equipment for fingerprint processing and identification, including Automated Fingerprint Identification System (AFIS) interface equipment
  - Mobile evidence collection and storage systems, including bags, canisters, and other containers for evidence storage and preservation
  - Equipment and consumable supplies for crime scene processing activities, including latent fingerprint collection, evidence collection, and documentation
  - Alternate light source equipment for crime scene processing
  - Tools to collect fingerprints from the deceased
- Training — establishing, supporting, conducting, and attending training specifically identified under the SHSP and UASI programs and/or in conjunction with emergency preparedness training by other federal agencies (e.g., the Department of Health and Human Services and the Department of Transportation).
- Exercises — staff/contractors, travel, and supplies
- Management and administration (5% cap)
- Other uses:
  - Maintenance and sustainment
  - Terrorism prevention activities by law enforcement, including information sharing and analysis, threat recognition, terrorist interdiction, training/hiring of intelligence analysts, and other analytical and investigative efforts
  - Construction (limited)
  - Personnel, including training and exercise coordinators, program managers for activities directly associated with SHSP- and UASI-funded activities, intelligence analysts, and statewide interoperability coordinators

Forensic laboratories and medical examiner/coroner (ME/C) offices should consider outreach to their SAA to identify ways to participate in the HSGP. Laboratories and ME/C offices are also encouraged to review the list of Core Capabilities (e.g., forensics and attribution, intelligence and information sharing, and fatality management services) to assess their state and local preparedness needs. [374] Likewise, SAAs, state senior advisory committees, and urban area working groups that participate in Department of Homeland Security/FEMA preparedness programs should collaborate and coordinate with their forensic laboratories and ME/C stakeholder counterparts when developing HSGP activities, particularly when developing the annual THIRA and SPR. Engagement with ME/Cs is particularly important for mass casualty incident preparedness.

As discussed in the 2009 NAS report, the medicolegal death investigation (MDI) community has also identified needs associated with its role in mass disasters and critical incidents. [30] MDI LSPs noted their specific roles in mass casualty events, including the identification of decedents and next of kin notifications, as well as their role in disaster mortuary operations response teams (DMORT). [69, 375] LSPs noted that robust fingerprint searching, access to relevant databases, and implementation of Rapid DNA technologies (see the sidebar, "Rapid DNA") and DNA familial analysis can be critical for disaster victim identification. However, as noted above, the instrumentation and database infrastructure can be costly, impeding implementation. Some LSPs noted that they have developed partnerships with local or co-located public health laboratories, so that public health laboratory staff with similar science backgrounds are trained in the forensic laboratory methods and instrumentation

necessary for supporting routine forensic casework. Some ME/C offices are organized within the state public health system, which fosters partnerships that support sentinel testing protocols, joint functional exercises, and preparedness activities. [376]

ME/C offices also directly participate in family assistance center operations, and may even serve as the lead office for establishing a center following a mass casualty event. [377, 380] The MDI community has recommended the development of a disaster call center to collect and manage critical information for victim identification. [379] Resources are needed to ensure consistent response and management of operations for disaster events, which may affect death investigations for months or even years afterward. The CDC also recently published a "Reference Guide for Certification of Deaths in the Event of a Natural, Human-Induced, or Chemical/Radiological Disaster" to strengthen the consistency and accuracy of mortality data. [380] LSPs noted that resources are needed to implement these types of recommendations. Mass disasters and critical incidents may significantly affect forensic operations. Routine forensic casework and death investigation referrals do not stop during critical incidents, and surge support may be necessary to maintain a regular level of services for the community, requiring robust continuity of operation planning. [379]

IX. Research and Development

Needs:

- Dedicated funding sources for methods and technology research and development.
- Dedicated funding sources for evaluation of existing policies and procedures to increase efficiency and quality of service provision.
- Highly discriminating, accurate, reliable, cost-effective, and rapid methods for the identification, analysis, and interpretation of physical evidence.
- Additional forensic science doctoral programs to produce the necessary researchers to keep advancing the forensic sciences.
- Practitioner-driven research, in which universities and other research-oriented entities work with laboratories to identify needs and conduct research to develop evidence-based solutions that can be implemented into the workflows of forensic laboratories and medical examiner and coroner offices.

Challenges:

- Lack of dedicated federal funding for forensic science research and technology innovations.
- Research can be one of the first items to be defunded in times of budgetary austerity, and forensic laboratory personnel who contribute to research may be shifted to casework duties during times of large workloads.
- Lack of access to scientific literature.

Promising Practices:

- The National Institute of Justice (NIJ) is leading efforts for forensic science research, development, and innovations, and there are several federally funded grants that allow for research and evaluations.
- NIJ's Forensic Technology Center of Excellence (FTCoE) facilitates the transfer of technology, methodologies, and best practices into forensic laboratories in order to improve the practice of forensic science.

For science — and the forensic sciences in particular — to advance, there must be continuous research, innovation, and the development of new methods, practices, and equipment. Existing policies and procedures must also be continually evaluated. As noted in the personnel section of this report, there is a shortage of doctoral programs in forensic science, which means that there are often not enough researchers to tackle the plethora of topics needing attention. While there are a wide variety of sources for funding and opportunities for research discussed throughout this report, listening session participants (LSPs) determined that this need is important to the broader forensic science community.

While agencies acknowledge the importance of research, they face multiple competing funding priorities. Research, which does not immediately translate to faster or more efficient casework, can be one of the first items defunded in times of budgetary austerity, and forensic personnel who contribute to research may be reallocated to address increasing workloads. NIJ is leading the effort to address these issues and is committed to the National Academy of Sciences' (NAS) 2015 affirmation that NIJ should continue to build its "capacity to support high-quality forensic science research." The 2015 NAS report also found that the efforts of NIJ have: "(1) restored authority that is appropriate for a science agency and addressed some previous concerns about NIJ's independence; and (2) contributed to the building of a research infrastructure necessary to develop and sustain research that advances forensic science methods." [31]

Continuous development of a national forensic science research infrastructure is hindered by a lack of dedicated federal grant funding needed to advance the speed, accuracy, and scope of forensic analysis for all types of evidence. NIJ and the other federal agencies rely on programmatic funds to maintain the continuous growth and strengthening of the forensic sciences, and a 2016 landscape study demonstrated the breadth of federal investments. [381] Since 2009, NIJ has supported more than 500 research and development awards related to forensic science totaling over $227.0 million. In fiscal year 2018, NIJ made 51 awards totaling nearly $24 million, many of which include projects that respond directly to the operational needs of crime laboratories and medical examiner/coroner (ME/C) offices. Advancements in science and technology require consistent support to develop these long-term solutions for helping to solve crimes.

To improve and advance the practice of forensic science, it is imperative that new technologies and methodologies be practitioner driven and adopted in forensic testing. LSPs noted that universities and other research-oriented entities need to work with laboratories to identify needs, and then conduct research for developing evidence-based solutions to the needs identified. One of the challenges involved in implementing research and development products and making them widely available is identifying industry partners who can commercialize and promulgate new technologies. Partnerships can accelerate meaningful academic-industrial research with both operational laboratories and commercial entities that develop technologies used in the forensic laboratory. The National Science Foundation (NSF) Industry/University Cooperative Research Centers (NSF-I/UCRC) program enables industrially relevant, precompetitive research via multimember, sustained partnerships among industry, academic institutions, and government. [382]

Through the NSF-I/UCRC model, the Center for Advanced Research in Forensic Science (CARFS) [383, 384] has facilitated this type of partnership. CARFS brings together industrial partners — including the end-user community (i.e., forensic science laboratories) — with academic forensic science researchers. Its aim is to develop, implement, and commercialize tools that benefit the national forensic science research enterprise. CARFS research programs include forensic chemistry, digital forensics/data analytics, forensic molecular biology, behavioral sciences, forensic anthropology, and forensic microbiology. After two years of operation, CARFS has funded almost $1 million in applied research in response to industry-initiated research needs. [384]

Alternatively, research partnerships can begin as simple information-sharing agreements. Several NIJ funding opportunities address these objectives, including the Research and Development in Forensic Science for Criminal Justice Purposes grant program and the Research and Evaluation for the Testing and Interpretation of Physical Evidence in Publicly Funded Forensic Laboratories grant program. [207, 385] The intent of the Research and Development in Forensic Science for Criminal Justice Purposes program is to direct the findings of basic scientific research; foster research and development in broader scientific fields applicable to forensic science; and support ongoing forensic science research toward the development of highly discriminating, accurate, reliable, cost-effective, and rapid methods for the identification, analysis, and interpretation of physical evidence for criminal justice purposes. Awardees propose projects that address the challenges and needs of the forensic science community, paying specific attention to the operational needs discussed at NIJ's Forensic Science Technology Working Group meetings and to the research needs identified on the Organization of Scientific Area Committees website. [386, 387] The Research and Evaluation for the Testing and Interpretation of Physical Evidence in Publicly Funded Forensic Laboratories program was developed to fund projects that direct the findings of research and evaluation toward the identification of the most efficient, accurate, reliable, and cost-effective methods for the identification, analysis, and interpretation of physical evidence for criminal justice purposes. Specifically, this grant program seeks applications that identify and inform the forensic community of best practices through the evaluation of existing laboratory protocols and/or applications that have a direct and immediate impact on laboratory efficiency and assist in making laboratory policy decisions.

Another way in which NIJ is addressing the need for forensic science research and development is through the Forensic Technology Center of Excellence (FTCoE). The FTCoE is charged with facilitating the transfer of technology, methodologies, and best practices into forensic laboratories in order to improve the practice of forensic science. The FTCoE is referenced throughout this report, as it plays a role in many aspects of advancing forensic science, such as the development and delivery of field-identified training needs, research and development on software and other technology, and supporting laboratories in addressing the opioid crisis. The FTCoE and similar research-oriented organizations allow for the implementation of new programs, such as efforts to strengthen the ME/C system in the United States. In response to several recent reports developed through national initiatives dedicated to improving the quality and practice of ME/C services, NIJ has committed to providing funding to:

- Support forensic pathology fellowships to increase the number and quality of board-certified forensic pathologists.

- Provide the resources necessary for ME/C offices to achieve accreditation.

The need for research also ties in to the need for additional doctoral programs. Doctoral students are the workforce for research and publication. Yet with few dedicated forensic science doctoral programs, the burden of research falls on the shoulders of faculty, who may not have the time or resources to complete grant-funded work within the period of performance. Although master's degree programs in the forensic sciences are more common, master's students may not be interested in research, even if their programs are structured to allow it. Without the necessary resource of inexpensive student labor, the amount and depth of research suffer.

Practitioner-university collaborations present other unique research opportunities that fall outside of work with traditional forensic science programs. Practitioners find it challenging to gain access to the peer-reviewed scientific research literature that is often easily available to university researchers. Practitioner-university collaborations also provide opportunities to partner with social scientists, particularly criminologists, who are trained in evaluation research. These partnerships can bring together the skills to examine the effectiveness of laboratory programs and initiatives and identify more ways to utilize the data generated by crime laboratories. Some LSPs noted that there is a great deal of untapped potential in crime laboratory data with regard to police and crime analysis applications.

X. Conclusions

This assessment is a snapshot in time. It is not an endpoint, but a starting point. The forensic science community has made great strides, demonstrating adaptability and resilience in addition to a focused commitment to advancing justice by improving service quality and service delivery. The underlying and unifying theme driving this report is that systems-based approaches are also strengths-based approaches in the forensic sciences. When all members of the system are united in a common goal and through a continuous, informed process, the justice system can work at optimal levels of service delivery and case processing. Throughout this report promising practices have been highlighted, both to give credit to innovative forensic science service providers, and also to provide models for other agencies and jurisdictions that can be adapted to each community's unique needs.

The impact of this assessment can already be observed in the forensic science community through the development of multiple training and policy initiatives, as well as the development of working groups that capitalize on systems-based approaches and mechanisms for sharing innovative strategies to address common challenges. As previously noted, the National Institute of Justice (NIJ) established the Forensic Laboratory Needs Technology Working Group (FLN-TWG) in 2018 to respond to the challenges identified through this needs assessment. [388-391] The FLN-TWG's mission is to provide objective and independent knowledge, data, information, and expertise to inform NIJ's decision-making process on the operational and implementation needs of federal, state, local, and tribal practitioners relating to forensic technology. NIJ anticipates that the FLN-TWG will: (1) identify forensic technology research needs; (2) provide input to NIJ about its forensic technology research agenda; (3) identify the need for new and improved technologies and practices; (4) disseminate information about promising forensic research, technologies, and practices to the field; and (5) help advance the implementation of relevant research, practices, and technologies.

NIJ also convened an opioid roundtable meeting in September 2018 that brought together stakeholders from the law enforcement and public health communities, including representatives from the forensic science community, to identify systems-based approaches and solutions for responding to the opioid crisis. NIJ is also coordinating with the American Society of Crime Laboratory Directors and through the Forensic Technology Center of Excellence (FTCoE) to deliver training on vicarious trauma in forensic professions.

Furthermore, the Bureau of Justice Statistics (BJS) remains committed to ascertaining the nature of forensic services provided by law enforcement agencies. This commitment is evident through BJS's plans to add a module to its next Law Enforcement Management and Administrative Statistics survey to begin initial analysis of what forensic services law enforcement agencies provide. BJS is also preparing to launch its second census of Medical Examiners and Coroners and sponsor another Census of Publicly Funded Forensic Crime Laboratories for 2019.

The forensic sciences have advanced, and with these advances have come specific, targeted needs that must be met. Current funding does not cover existing levels of service requests; all indicators show that these requests for service have increased over time, and they are projected to continue doing so. Lower-priority expenditures, such as continuing education and training, accreditation efforts, facilities and equipment improvement projects, and research and development, may be cut because of a shortage of resources. While these expenditures are all necessary for advancing the field and for seeking to provide the best service delivery to clients, they may be sacrificed in some cases in an effort to simply fund the current requests for service. Investments in personnel, facilities, infrastructure, and research and development are necessary for continuing to propel the field forward along its current trajectory of advancement, and for demonstrating a firm commitment to providing clients with timely, efficient case processing.

XI. Acknowledgments

The U.S. Department of Justice (DOJ) gratefully acknowledges the individuals who contributed to the development and review of the Needs Assessment, especially Amanda Farrell, Ph.D., assistant professor of Criminal Justice, Marymount University, consultant technical writer for this project; and Paul Speaker, Ph.D., Department of Finance, John Chambers College of Business and Economics, West Virginia University; Max Houck, Ph.D., managing director, Forensic and Intelligence Services, St. Petersburg, Florida; and Amanda Jones, West Virginia University, for their consultant analysis of data from Project FORESIGHT and contributions for the academic overview. DOJ also acknowledges significant contributions from the National Institute of Justice's (NIJ) Office of Investigative and Forensic Sciences, especially Jonathan McGrath, Ph.D., senior policy analyst for forensic science; Lindsay DePalma, Booz Allen Hamilton, technical consultant to NIJ; and Gerald LaPorte, former director of NIJ's Office of Investigative and Forensic Sciences.

Recognition is also given to those who contributed at various listening sessions and information-gathering discussions to better inform this report and provide a thorough needs assessment that considers various stakeholder groups and viewpoints within the forensic sciences.

XII. References

1. Justice for All Reauthorization Act of 2016 (JFARA), S.2577 C.F.R. § 16. (2016). https://www.congress.gov/bill/114th-congress/senate-bill/2577.
2. National Institute of Standards and Technology (NIST): Office of Law Enforcement Standards. (1999). Forensic sciences: Review of status and needs. Retrieved from Washington, DC: https://www.ncjrs.gov/pdffiles1/173412.pdf.
3. Durose, M. R., Walsh, K. A., & Burch, A. M. (2012). Census of publicly funded forensic crime laboratories, 2009. U.S. Department of Justice (DOJ), Office of Justice Programs (OJP), Bureau of Justice Statistics (BJS). Washington, DC: Retrieved from https://www.bjs.gov/content/pub/pdf/cpffcl09.pdf.
4. Peterson, J. L., & Hickman, M. J. (2005). Census of publicly funded forensic crime laboratories, 2002. U.S. Department of Justice (DOJ), Office of Justice Programs (OJP), Bureau of Justice Statistics (BJS). Washington, DC: Retrieved from https://www.bjs.gov/content/pub/pdf/cpffcl02.pdf.
5. Burch, A. M., Durose, M. R., Walsh, K. A., & Tiry, E. (2016). Publicly funded forensic crime laboratories: Quality assurance practices, 2014. U.S. Department of Justice (DOJ), Office of Justice Programs (OJP), Bureau of Justice Statistics (BJS). Washington, DC: Retrieved from https://www.bjs.gov/content/pub/pdf/pffclqap14.pdf.
6. U.S. Department of Justice (DOJ), Office of Justice Programs (OJP), National Institute of Justice (NIJ). (1999). Forensic sciences: Review of status and needs. Retrieved from https://www.ncjrs.gov/pdffiles1/173412.pdf.
7. National Science and Technology Council, Committee on Science. (2016). Strengthening the medicolegal-death-investigation system: Improving data systems. Retrieved from https://www.ncjrs.gov/pdffiles1/NIJ/251423.pdf.
8. Hanzlick, R. L. (2014). A perspective on medicolegal death investigation in the United States: 2013. *Academic Forensic Pathology*, *4*(1), 2-9. https://doi.org/10.23907/2014.001.
9. National Association of Medical Examiners (NAME). (2004). Preliminary report on America's medicolegal offices, prepared for National Institute of Justice (NIJ), Forensic Summit. Retrieved from https://www.ncjrs.gov/pdffiles1/nij/grants/213421.pdf.

10. Committee on Science, Medicolegal Death Investigation Working Group (MDI WG), National Science and Technology Council. (2016). Strengthening the medicolegal-death-investigation system: Accreditation and certification: A path forward. Retrieved from http://www.thecfso.org/advocacy/2017/OSTP_accreditation_recommendation.pdf.

11. System Infrastructure Committee, Scientific Working Group on Medicolegal Death Investigation (SWGMDI). (2013). Regional medicolegal autopsy and death investigation centers: Construction, staffing, and costs. Retrieved from https://swgmdi.org/images/si6.facilityconstruction.published.9-17-13.pdf.

12. Hickman, M. J., Hughes, K. A., Strom, K. J., & Ropero-Miller, J. D. (2007). Medical examiners and coroners' offices, 2004. U.S. Department of Justice (DOJ), Office of Justice Programs (OJP), Bureau of Justice Statistics (BJS). Washington, DC: Retrieved from http://purl.fdlp.gov/GPO/gpo2457.

13. Strom, K. J., Ropero-Miller, J., Jones, S., Sikes, N., Pope, M., & Horstmann, N. (2009). The 2007 survey of law enforcement forensic evidence processing: Final report submitted to the National Institute of Justice. Retrieved from https://www.ncjrs.gov/pdffiles1/nij/grants/228415.pdf.

14. Strom, K. J., & Hickman, M. J. (2010). Unanalyzed evidence in law-enforcement agencies. *Criminology & Public Policy, 9*(2), 381-404. https://doi.org/10.1111/j.1745-9133.2010.00635.x.

15. Samarji, A. (2012). Forensic science education: Inquiry into current tertiary forensic science courses. *Forensic Science Policy & Management: An International Journal, 3*(1), 24-36. https://doi.org/10.1080/19409044.2012.719580.

16. Technical Working Group for Education (TWGED). (2004). Education and training in forensic science: A guide for forensic science laboratories, educational institutions, and students. Retrieved from www.fepac-edu.org/sites/default/files/pdf/NIJReport.pdf.

17. Tregar, K. L., & Proni, G. (2010). A review of forensic science higher education programs in the United States: Bachelor's and master's degrees. *Journal of Forensic Sciences, 55*(6), 1488-1493. https://doi.org/10.1111/j.1556-4029.2010.01505.x.

18. Collins, K. A. (2015). The future of the forensic pathology workforce. *Academic Forensic Pathology, 5*(4), 526-533. https://doi.org/10.23907/2015.058.

19. Bethard, J. D. (2017). Historical trends in graduate research and training of diplomates of the American Board of Forensic Anthropology. *Journal of Forensic Sciences, 62*(1), 5-11. https://doi.org/10.1111/1556-4029.13262.

20. Warren, M. W., Van Deest, T., & Ballard, K. (2011). Quality assurance as pedagogy for academic forensic anthropology laboratories. *Forensic Science Policy & Management: An International Journal, 2*(2), 70-74. https://doi.org/10.1080/19409044.2011.579227.

21. Childs, R. A., Witt, T. S., & Nur-tegin, K. (2009). Survey of forensic service providers. *Forensic Science Policy and Management, 1*(1), 49-56. https://doi.org/10.1080/19409040802626401.

22. Robertson, J., White, R., Kelty, S., & Julian, R. (2014). Professionalization and crime scene examination. *Forensic Science Policy & Management: An International Journal, 5*(3-4), 99-111. https://doi.org/10.1080/19409044.2014.981348.

23. Houck, M. M., Riley, R. A., Speaker, P. J., & Witt, T. S. (2009). FORESIGHT: A business approach to improving forensic science services. *Forensic Science Policy & Management, 1*(2), 85-95. https://doi.org/10.1080/19409040902810723.

24. Kurimski, L. M., Speaker, P. J., & Bassler, J. R. (2017). Project FORESIGHT and return on investment: Forensic science laboratories and public health laboratories. *Forensic Science Policy & Management, 8*(1/2), 1-12. https://doi.org/10.1080/19409044.2017.1280099.

25. Newman, J., Dawley, D., & Speaker, P. J. (2011). Strategic management of forensic laboratory resources: From Project FORESIGHT metrics to the development of action plans. *Forensic Science Policy & Management, 2*(4), 164-174. https://doi.org/10.1080/19409044.2012.693571.

26. Speaker, P. J. (2009). Key performance indicators and managerial analysis for forensic laboratories. *Forensic Science Policy and Management, 1*(1), 32-42. https://doi.org/10.1080/19409040802624075.

27. National Institute of Standards and Technology (NIST). (n.d.). Forensic Science. Retrieved from https://www.nist.gov/topics/forensic-science.

28. National Science Foundation (NSF). (n.d.). National Science Foundation Homepage. Retrieved from https://www.nsf.gov/.

29. Executive summary of the National Academies of Science reports, Strengthening forensic science in the United States: A path forward. (2009). *Forensic Science Policy & Management, 1*(2), 106-122. https://doi.org/10.1080/19409040902844128.

30. Committee on Identifying the Needs of the Forensic Sciences Community, National Research Council. (2009). Strengthening forensic science in the United States: A path forward. NIJ Award 2006-DN-BX-0001. NCJ 228091. Retrieved from https://www.ncjrs.gov/pdffiles1/nij/grants/228091.pdf.

31. Committee on Strengthening Forensic Science at the National Institute of Justice (NIJ), Committee on Law and Justice: Division of Behavioral and Social Sciences and Education, & National Academies of Sciences, Engineering, and Medicine. (2015). Support for forensic science research: Improving the scientific role of the National Institute of Justice. Retrieved from https://sites.nationalacademies.org/DBASSE/CLAJ/Support_for_Forensic_Science_Research/index.htm.

32. Committee on Science, Subcommittee on Forensic Science, National Science and Technology Council. (2014). Strengthening the forensic sciences. Retrieved from https://www.ncjrs.gov/pdffiles1/NIJ/251422.pdf.

33. Durose, M. R., Walsh, K. A., & Burch, A. M. (2008). Census of publicly funded forensic crime laboratories, 2005. U.S. Department of Justice (DOJ), Office of Justice Programs, Bureau of Justice Statistics (BJS). Washington, DC: Retrieved from https://www.bjs.gov/content/pub/pdf/cpffcl05.pdf.

34. Durose, M. R., Burch, A. M., Walsh, K., & Tiry, E. (2016). Publicly funded forensic crime laboratories: Resources and services, 2014. U.S. Department of Justice (DOJ), Office of Justice Programs (OJP), Bureau of Justice Statistics (BJS). Washington, DC: Retrieved from https://www.bjs.gov/content/pub/pdf/pffclrs14.pdf.

35. Wisconsin Department of Justice. AG Schimel's reforms improving turnaround of evidence at state crime lab but more support needed through funding, staffing, and technology. (2018). [Press release]. Retrieved from https://www.doj.state.wi.us/news-releases/ag-schimel%E2%80%99s-reforms-improving-turnaround-evidence-state-crime-lab-more-support-needed.

36. National Forensic Science Technology Center at Florida International University. (2018). Wisconsin State Crime Laboratory Bureau needs assessment report. Retrieved from https://www.doj.state.wi.us/content/matthew-murray-wisconsin-state-crime-laboratory-bureau-needs-assessment-report.

37. U.S. Department of Justice (DOJ). (2019). Needs assessment of forensic laboratories supplemental materials: Project FORESIGHT econometric analysis. Retrieved from https://www.justice.gov/olp/forensic-science#needs.

38. Johns, S. (2004). 180-day study report: Status and needs of United States crime laboratories. Retrieved from https://www.ncjrs.gov/pdffiles1/nij/grants/213422.pdf.

39. Forensic Science Education Programs Accreditation Commission (FEPAC). (2019). Forensic Science Education Programs Accreditation Commission Home Page. Retrieved from http://fepac-edu.org/.

40. Forensic Science Education Programs Accreditation Commission (FEPAC). (Updated 2019). Accredited universities. Retrieved from http://fepac-edu.org/accredited-universities.

41. U.S. Department of Justice (DOJ), Office of Justice Programs (OJP), National Institute of Justice (NIJ). (2019). Connecting postgraduate researchers with publicly-funded forensic laboratories. Retrieved from https://www.nij.gov/topics/forensics/lab-operations/Pages/connecting-postgraduate-researchers-with-publicly-funded-forensic-laboratories.aspx.

42. Entomological Society of America (ESA). (n.d.). Undergraduate entomology programs. Retrieved from https://www.entsoc.org/resources/education/undergraduate.

43. Entomological Society of America (ESA). (n.d.). Entomology graduate-degree programs. Retrieved from https://www.entsoc.org/resources/education/colleges.

44. Forensics Colleges. (2018). 7 universities with forensic entomology programs. Retrieved from https://www.forensicscolleges.com/blog/resources/college-forensic-entomology-programs.

45. Dowd, M. (2018). Education required for forensic anthropology. Retrieved from https://work.chron.com/education-required-forensic-anthropology-6835.html.

46. American Board of Forensic Anthropology (ABFA). (2018). The American Board of Forensic Anthropology. Retrieved from http://theabfa.org/.

47. American Board of Forensic Anthropology. (2018). Active Diplomates. Retrieved from http://theabfa.org/active-diplomates/.

48. Syracuse University. (2018). Medicolegal death investigation, MS. Graduate degree program. Retrieved from http://coursecatalog.syr.edu/preview_program.php?catoid=14&poid=7374&hl=%22Medicolegal+Death%22&returnto=search&_ga=2.249035527.1014524992.1521735848-2072442204.1521735848.

49. Philadelphia College of Osteopathic Medicine. (2018). Forensic medicine, MS. Graduate degree program. Retrieved from https://www.pcom.edu/academics/programs-and-degrees/forensic-medicine/.

50. University of Maryland. (2013). Forensic medicine, MS. Graduate degree program. Retrieved from http://www.graduate.umaryland.edu/forensicmedicine/.

51. University of Florida Health. (2018). Forensic medicine education program, MS. Graduate degree program. Retrieved from https://forensicmedicine.med.ufl.edu/program/.

52. University of Florida Health. (2018). Graduate certificate in forensic death investigation. Retrieved from https://forensicscience.ufl.edu/programs/graduate-certificate/forensic-death-investigation/.

53. Zusi, K. (2016). Breaking out of the academic pipeline. *Cell, 165*(7), 1557-1559. https://doi.org/10.1016/j.cell.2016.06.007.

54. National Science Foundation (NSF). (n.d.). Research experiences for undergraduates (REU). Retrieved from https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5517.

55. Bureau of Labor Statistics. (2018). Occupational outlook handbook: Forensic science technicians. Retrieved from https://www.bls.gov/ooh/life-physical-and-social-science/forensic-science-technicians.htm.

56. Forensic Science Education Programs Accreditation Commission (FEPAC). (2017). Accreditation standards. Retrieved from http://fepac-edu.org/sites/default/files/FEPAC%20Standards%2002122017%20v3.pdf.

57. Moorehead, W. (2011). Forensic interns: Force multipliers in the crime lab. *Forensic Science Policy & Management: An International Journal, 2*(3), 118-134. https://doi.org/10.1080/19409044.2011.638361.

58. American Society of Crime Laboratory Directors (ASCLD). (2004). 180-day study report: Status and needs of United States crime laboratories. Retrieved from https://www.ncjrs.gov/pdffiles1/nij/grants/213422.pdf.

59. Federal Bureau of Investigation (FBI). (2011). Quality assurance standards for forensic DNA testing laboratories. Retrieved from http://media.wix.com/ugd/4344b0_4a22824ce56f43d4b1a4d2486409f95d.pdf.

60. National Institute of Justice (NIJ). (2004). Status and needs of forensic science service providers: A report to Congress. Retrieved from Washington, DC: https://www.ncjrs.gov/pdffiles1/nij/213420.pdf.

61. National Commission on Forensic Science (NCFS), National Institute of Standards and Technology (NIST). (2016). Views of the Commission: Certification of forensic science practitioners. Retrieved from https://www.justice.gov/archives/ncfs/page/file/905897/download.

62. U.S. Department of Justice (DOJ), Office of Justice Programs (OJP), Bureau of Justice Statistics (BJS). (2017). Census of publicly funded forensic crime laboratories, 2014. Ann Arbor, MI: Inter-university Consortium for Political and Social Research, National Archive of Criminal Justice Data. https://doi.org/10.3886/ICPSR36759.v1.

63. Jeanguenat, A. M., & Dror, I. E. (2018). Human factors effecting forensic decision making: Workplace stress and well-being. *Journal of Forensic Sciences, 63*(1), 258-261. https://doi.org/10.1111/1556-4029.13533.

64. Flarity, K., Nash, K., Jones, W., & Steinbruner, D. (2016). Intervening to improve compassion fatigue resiliency in forensic nurses. *Advanced Emergency Nursing Journal, 38*(2), 147-156. https://doi.org/10.1097/TME.0000000000000101.

65. Holt, T. J., Blevins, K. R., Foran, D. R., & Smith, R. W. (2016). Examination of the conditions affecting forensic scientists' workplace productivity and occupational stress. Retrieved from https://www.nij.gov/topics/forensics/lab-operations/Pages/conditions-affecting-forensic-scientists-workplace-productivity-and-stress.aspx.

66. Levin, A. P. (2018). Management of stress and burnout in the workplace. Paper presented at the American Society of Crime Laboratory Directors (ASCLD) Symposium 2018. https://www.ascld.org/meetings-and-training/ascld-annual-symposium/.

67. Salinas, C., & Webb, H. (2018). Occupational stress and coping mechanisms in crime scene personnel. *Occupational Medicine, 68*(4), 239-245. https://doi.org/10.1093/occmed/kqy030.

68. Henry, V. E. (2004). *Death work: Police, trauma, and the psychology of survival.* New York: Oxford University Press: https://global.oup.com/academic/product/death-work-9780195157659?cc=us&lang=en&.

69. Scientific Working Group for Medicolegal Death Investigation (SWGMDI). (2012). Principles for communicating with next of kin during medicolegal death investigations. Retrieved from https://swgmdi.org/images/nokguidelinesforcommunicationwithnok6.14.12%202.pdf.

70. Scientific Working Group for Medicolegal Death Investigation (SWGMDI). (2012). Principles for critical stress management in MDI settings: Critical event debriefing and recommendations for development. Retrieved from https://swgmdi.org/images/nokprinciplescriticalstressmgtinmdipublished6.14.12.pdf.

71. Kirschman, E., Kamena, M., & Fay, J. (2015). *Counseling cops: What clinicians need to know.* New York: Guilford Press. https://www.guilford.com/books/Counseling-Cops/Kirschman-Kamena-Fay/9781462524303.

72. U.S. Department of Justice (DOJ), Office of Justice Programs (OJP), Office for Victims of Crime (OVC). (n.d.). The Vicarious Trauma Toolkit (VTT). OJJDP Award Number 2016-MC-FX-K023. Retrieved from https://vtt.ovc.ojp.gov/about-the-toolkit.

73. Shift Wellness. (n.d.). We're Shift Wellness: Supporting heroes in mental health foundational training. The Innocent Justice Foundation. Retrieved from https://www.shiftwellness.net/.

74. Burns, C. M., Morley, J., Bradshaw, R., & Domene, J. (2008). The emotional impact on and coping strategies employed by police teams investigating internet child exploitation. *Traumatology, 14*(2), 20-31. https://doi.org/10.1177/1534765608319082.

75. Iorga, M., Soponaru, C., & Ioan, B. (2016). The burnout syndrome of forensic pathologists: The influences of personality traits, job satisfaction and environmental factors. *Romanian Journal of Legal Medicine, 24*(4), 325-332. http://www.rjlm.ro/system/revista/40/325-332.pdf.

76. Krause, M. (2009). Identifying and managing stress in child pornography and child exploitation investigators. *Journal of Police and Criminal Psychology, 24*(1), 22-29. https://doi.org/10.1007/s11896-008-9033-8.

77. Stevens, D. J. (2005). Police officer stress and occupational stressors. In H. Copes (ed.), *Policing and Stress,* (pp. 1-24). Upper Saddle River, NJ: Pearson Education. https://www.amazon.com/Policing-Stress-Heith-Copes/dp/0131123718.

78. Violanti, J. M. (2005). Dying for the job: Psychological stress, disease and mortality in police work. In H. Copes (ed.), *Policing and Stress,* (pp. 87-102). Upper Saddle River, NJ: Pearson Education. https://www.amazon.com/Policing-Stress-Heith-Copes/dp/0131123718.

79. National Academy of Medicine. (2018). Action Collaborative on Clinician Well-Being and Resilience. Retrieved from https://nam.edu/initiatives/clinician-resilience-and-well-being/.

80. Brondolo, E., Wellington, R., Brady, N., Libby, D., & Brondolo, T. (2008). Mechanism and strategies for preventing post-traumatic stress disorder in forensic workers responding to mass fatality incidents. *Journal of Forensic and Legal Medicine, 15*(2), 78-88. https://doi.org/10.1016/j.jflm.2007.04.007.

81. International Critical Incident Stress Foundation (ICISF). (2018). CISM Teams and Support. Retrieved from https://icisf.org/sections/cism-teams/.

82. Federal Law Enforcement Training Centers (FLETC). (2015). Critical Incident Stress Management (CISM) & Peer Support Program. Department of Homeland Security (DHS). Retrieved from https://www.fletc.gov/critical-incident-stress-management-cism-peer-support-program.

83. Code 9 Project. (2015). Making mental health a priority for all first responders and their families. Retrieved from http://www.code9project.org/index.html.

84. Farrell, A. L., & Ainger, T. (2018). Trauma, cognition, and the investigators. Paper presented at the Annual Meeting of the American Academy of Forensic Sciences (AAFS), Seattle, WA. https://www.aafs.org/wp-content/uploads/2018FINALPROGRAM.pdf.

85. Farrell, A.L., Ainger, T., Scallon, C.J.A., & Huffman, L. (2019). What's trauma and stress got to do with it? Recognizing the impact of trauma on forensic professionals and taking steps to mitigate it. Half-day workshop presented at the Annual Meeting of the American Academy of Forensic Sciences (AAFS). Baltimore, MD. https://www.aafs.org/wp-content/uploads/CompleteProceedings19PM.pdf.

86. Farrell, A.L., & Ainger, T. (2019). Stress, trauma and the forensic workforce: Taking steps to recognize and address the issues. Half-day workshop invited and presented for the Annual Meeting of the Mid-Atlantic Association of Forensic Scientists (MAAFS). Morgantown, WV. https://docs.wixstatic.com/ugd/699764_2b8f511ff10a43d193037fd20762bc85.pdf.

87. McKay-Davis, S. (2018). Comparison of civilian forensic technician and sworn peace officer job related stress. Paper presented at the 103rd IAI Educational Conference, San Antonio, TX. https://www.eiseverywhere.com/ehome/307573/683201/?t=8f6c8c4d65a5efdea03eb3f09e910a11.

88. Haynes, C., & Pettolina, M. (2018). There's an elephant in the room. Paper presented at the 103rd International Association for Identification (IAI) International Educational Conference, San Antonio, TX. https://www.eiseverywhere.com/ehome/307573/683201/?t=8f6c8c4d65a5efdea03eb3f09e910a11.

89. Patel, J. (2018). Secondary traumatization: My story. Paper presented at the 103rd International Association for Identification (IAI) International Education Conference, San Antonio, TX. https://www.eiseverywhere.com/ehome/307573/683201/?t=8f6c-8c4d65a5efdea03eb3f09e910a11.

90. Christiansen, D. (2018). Psychological survival in a violent career. Paper presented at the 103rd International Association for Identification (IAI) International Education Conference, San Antonio, TX. https://www.eiseverywhere.com/ehome/307573/683201/?t=8f6c8c4d65a5efdea03eb3f09e910a11.

91. Forensic Technology Center of Excellence (FTCoE). (2018). Forensic workforce resiliency: Vicarious trauma & workplace stress webinar series. Retrieved from https://forensiccoe.org/webinar/vicarious-trauma-workplace-stress-series/.

92. Spence, D. L., Fox, M., Moore, G. C., Estill, S., & Comrie, N. E. A. (2019). Law Enforcement Mental Health and Wellness Act: A report to Congress. U.S. Department of Justice (DOJ), Community Oriented Policing Services (COPS). Retrieved from https://cops.usdoj.gov/pdf/2019AwardDocs/lemhwa/Report_to_Congress.pdf.

93. U.S. Department of Justice (DOJ), Office of Justice Programs (OJP), Bureau of Justice Statistics (BJS). (2018). Census of publicly funded forensic crime laboratories, 2009 (v.2). Ann Arbor, MI: Inter-university Consortium for Political and Social Research, National Archive of Criminal Justice Data, https://doi.org/10.3886/ICPSR34340.v2.

94. Forensic Technology Center of Excellence (FTCoE). (2016). Strengthening forensic science services through National Institute of Justice grant programs — 2016 crime laboratory directors' meeting. Retrieved from https://rti.connectsolutions.com/cld2016/.

95. Forensic Technology Center of Excellence (FTCoE). (2014). Strengthening forensic science services through the DNA Capacity Enhancement & Backlog Reduction (CEBR) Program and Paul Coverdell Forensic Science Improvement Grants, Final Report. NIJ Award Number 2011-DN-BX-K564. NCJ 248540. Retrieved from https://www.ncjrs.gov/pdffiles1/nij/grants/248540.pdf.

96. National Institute of Justice (NIJ). (2018). Coverdell National Forensic Science Improvement Grants Program. Retrieved from https://nij.gov/topics/forensics/lab-operations/capacity/nfsia/Pages/welcome.aspx.

97. U.S. Department of Justice (DOJ), Office of Justice Programs (OJP), Bureau of Justice Statistics (BJS). (2017). Census of publicly funded forensic crime laboratories, 2014. Ann Arbor, MI: Inter-university Consortium for Political and Social Research, National Archive of Criminal Justice Data. https://doi.org/10.3886/ICPSR36759.v1.

98. LaPorte, G., Waltke, H., Heurich, C., & Chase, R. (2018). NIJ fiscal year 2017 funding for DNA analysis, capacity enhancement, and other forensic activities. Retrieved from https://www.ncjrs.gov/pdffiles1/nij/251445.pdf.

99. Nelson, M. S., Chase, R., & DePalma, L. (2013). Making sense of DNA backlogs, 2012: Myths vs. reality. Retrieved from https://www.ncjrs.gov/pdffiles1/nij/243347.pdf.

100. Dutton, G. J., Laporte, G. M., Wagstaff, I. R., & Spivak, H. R. (2017). Cultivating the next generation of forensic scientists through science, technology, engineering, and mathematics (STEM). *Journal of Forensic Research, 8.* doi:10.4172/2157-7145.1000384.

101. Speaker, P. (2017). Project FORESIGHT annual report, 2015-2016. Retrieved from https://researchrepository.wvu.edu/faculty_publications/1144.

102. Strom, K. J., & Hickman, M. J. (2015). *Forensic science and the administration of justice: Critical issues and directions.* Thousand Oaks, CA: SAGE Publications. https://us.sagepub.com/en-us/nam/forensic-science-and-the-administration-of-justice/book240380.

103. Strom, K. J., Hickman, M. J., Smiley Mcdonald, H. M., Ropero-Miller, J. D., & Stout, P. M. (2011). Crime laboratory personnel as criminal justice decision makers: A study of controlled substance case processing in ten jurisdictions. *Forensic Science Policy & Management: An International Journal, 2*(2), 57-69. https://doi.org/10.1080/19409044.2011.573837.

104. Jackson, B. A., Banks, D., Hollywood, J. S., Woods, D., Royal, A., Woodson, P. W., & Johnson, N. J. (2016). Fostering innovation in the U.S. court system — Identifying high-priority technology and other needs for improving court operations and outcomes. In: RAND Corporation: https://www.rand.org/content/dam/rand/pubs/research_reports/RR1200/RR1255/RAND_RR1255.pdf.

105. International Organization for Standardization (ISO). (n.d.). ISO/IEC 17020 – Conformity assessment – Requirements for the operation of various types of bodies performing inspection. Retrieved from https://www.iso.org/standard/52994.html.

106. International Organization for Standardization (ISO). (n.d.). ISO/IEC 17025 – General requirements for the competence of testing and calibration laboratories. Retrieved from https://www.iso.org/home/standards/popular-standards/isoiec-17025-testing-and-calibra.html.

107. Federal Bureau of Investigation (FBI). (2019). CODIS - NDIS Statistics. Retrieved from https://www.fbi.gov/services/laboratory/biometric-analysis/codis/ndis-statistics.

108. Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF). (2018). Fact sheet - National Integrated Ballistic Information Network. Retrieved from https://www.atf.gov/resource-center/fact-sheet/fact-sheet-national-integrated-ballistic-information-network.

109. National Missing and Unidentified Persons System (NamUs). (2019). About NamUs. Retrieved from https://www.namus.gov/About.

110. Federal Bureau of Investigation (FBI). (n.d.). The Integrated Automated Fingerprint System. Retrieved from https://www.fbi.gov/file-repository/about-us-cjis-fingerprints_biometrics-biometric-center-of-excellences-iafis_0808_one-pager825/view.

111. National Institute of Justice (NIJ). (2013). Social science research on forensic science topical working group meeting. Paper presented at the Social Science Research on Forensic Science Topical Working Group Meeting, Washington, DC. Retrieved from https://www.ncjrs.gov/pdffiles1/nij/244261.pdf.

112. Virginia Department of Forensic Science. (2019). Evidence handling and laboratory capabilities guide. Retrieved from https://www.dfs.virginia.gov/documentation-publications/evidence-handling-and-laboratory-capabilities-guide/.

113. Houston Forensic Science Center. (2019). Houston Forensic Science Center. Retrieved from http://www.houstonforensicscience.org/index.php.

114. Forensic Technology Center of Excellence (FTCoE). (2018). Process and outcome evaluation of forensic DNA unit efficiency improvement program. Retrieved from https://forensiccoe.org/eip-forensic-dna-report-2018/?utm_source=Forensic+COE+Weekly+Newsletter&utm_campaign=08d6425ea7-Newsletter_10%2F26%2F16_COPY_01&utm_medium=email&utm_term=0_32592f10b8-08d6425ea7-13700113.

115. Forensic Science Initiative. (2018). Project FORESIGHT annual report, 2016-2017. West Virginia University, John Chambers College of Business & Economics. Retrieved from https://researchrepository.wvu.edu/faculty_publications/1140.

116. Speaker, P. J. (2015). Financial management of forensic science laboratories: Lessons from project FORESIGHT 2011-2012. *Forensic Science Policy & Management: An International Journal, 6*(1-2), 7-29. https://doi.org/10.1080/19409044.2015.1008604.

117. Heames, J. T., & Heames, J. T. (2011). Forensic science staffing: Creating a working formula. *Forensic Science Policy & Management: An International Journal, 2*(1), 5-10. https://doi.org/10.1080/19409044.2010.516796.

118. Wickenheiser, R. (2013). Forensic laboratory efficiency and funding. In J. A. Siegel & P. J. Saukko (eds.), *Encyclopedia of forensic sciences* (Vol. 1, pp. 344-350): Academic Press. https://www.cengage.com/search/productOverview.do;jsessionid=35D1C1E-346A3911B5F1DC26B22637127?N=197+4294891609+4294904586&Ntk=P_EPI&Ntt=60556203813925135261930002063873569542&Ntx=mode%2Bmatchallpartial.

119. Anderson, J. M., Matthias, C. F., Greathouse, S. M., & Chari, A. V. (2018). The unrealized promise of forensic science: An empirical study of its production and use. Retrieved from https://www.rand.org/content/dam/rand/pubs/working_papers/WR1200/WR1242/RAND_WR1242.pdf.

120. National Institute of Justice (NIJ). (2019). National best practices for implementing and sustaining a cold case investigation unit. Retrieved from https://www.ncjrs.gov/pdffiles1/nij/252016.pdf.

121. Forensic Science Laboratories Facilities Technical Working Group. (2013). Forensic science laboratories: Handbook for facility planning, design, construction, and relocation. Retrieved from https://nvlpubs.nist.gov/nistpubs/ir/2013/NIST.IR.7941.pdf.

122. Forensic Technology Center of Excellence (FTCoE). (2016). Development of a lean facility design roadmap for design-bid-build forensic facilities. Retrieved from https://rti.connectsolutions.com/p24lvtclk06/.

123. Hicks, C., McGovern, T., Prior, G., & Smith, I. (2015). Applying lean principles to the design of healthcare facilities. *International Journal of Production Economics, 170*, 677-686. https://doi.org/10.1016/j.ijpe.2015.05.029.

124. Police Executive Research Forum (PERF). (2017). The "Crime Gun Intelligence Center" model: Case studies of the Denver, Milwaukee, and Chicago approaches to investigating gun crime. Retrieved from https://crimegunintelcenters.org/wp-content/uploads/2017/07/CGIC-Model_CaseStudies_PERF-052017.pdf.

125. International Organization for Standardization (ISO). (n.d.). ISO 9000 family - Quality management. Geneva, Switzerland: ISO. https://www.iso.org/iso-9001-quality-management.html.

126. Collins, J. M., & Jarvis, J. (2009). The wrongful conviction of forensic science. *Forensic Science Policy and Management, 1*(1), 17-31. https://doi.org/10.1080/19409040802624067.

127. United Kingdom Accreditation Service (UKAS). (2017). ISO/IEC 17020 Accreditation for crime scene investigation – An overview. Retrieved from https://www.ukas.com/download/general_documents/ISO_IEC%2017020%20Accreditation%20for%20Crime%20Scene%20Investigation%20An%20Overview.pdf.

128. LaPorte, G. (2018). Wrongful convictions and DNA exonerations: Understanding the role of forensic science. *NIJ Journal, 279*, NCJ 250705. https://www.nij.gov/journals/279/Pages/wrongful-convictions-and-dna-exonerations.aspx.

129. Forensic Technology Center of Excellence (FTCoE). (2014). Final report to NIJ: American Society of Crime Laboratory Directors (ASCLD) data collection on forensic service providers. Retrieved from https://www.ascld.org/wp-content/uploads/2014/09/ASCLD_FTCOE_Forensic-ServiceProviders_Report_Sept-2014_FINAL-1-1-1.pdf.

130. National Commission on Forensic Science (NCFS). (2016). Views of the commission: Critical steps to accreditation. Retrieved from https://www.justice.gov/archives/ncfs/file/839701/download.

131. U.S. Department of Justice (DOJ). (2018). Forensic science. Retrieved from https://www.justice.gov/olp/forensic-science#posting.

132. Houston Forensic Science Center. (2019). Welcome to Houston Forensic Science Center record search. Retrieved from https://records.hfscdiscovery.org/Pages/Home.aspx.

133. Virginia Department of Forensic Science. (2019). Manuals and procedures. Retrieved from https://www.dfs.virginia.gov/documentation-publications/manuals.

134. Idaho State Police. (2019). Welcome to Idaho State Police Forensic Services. Retrieved from https://www.isp.idaho.gov/forensics.

135. District of Columbia Department of Forensic Sciences. (2019). Open government and FOIA – DFS. Retrieved from https://dfs.dc.gov/page/open-government-and-foia-dfs.

136. Austin Police Department. (2019). Forensic science – Policy manuals and forms. Retrieved from https://www.austintexas.gov/page/forensics-policy-manuals.

137. U.S. Department of Justice (DOJ), Office of Public Affairs. (2015). Justice Department announces new accreditation policies to advance forensic science. Press release. Retrieved from https://www.justice.gov/opa/pr/justice-department-announces-new-accreditation-policies-advance-forensic-science.

138. Lynch, L. E. (2015). Recommendations of the National Commission on Forensic Science. Press release. Retrieved from https://www.justice.gov/opa/pr/justice-department-announces-new-accreditation-policies-advance-forensic-science.

139. Centers for Disease Control and Prevention (CDC). (2015). Death investigation systems. Retrieved from https://www.cdc.gov/phlp/publications/coroner/death.html.

140. Centers for Disease Control and Prevention (CDC). (2015). Coroner training requirements. Retrieved from https://www.cdc.gov/phlp/publications/coroner/training.html.

141. Cunningham, K. S., & Pollanen, M. (2015). Evolution of a molecular autopsy program from within a death investigation system. *Academic Forensic Pathology, 5*(2), 211-220. https://doi.org/10.23907/2015.024.

142. Cunningham, K. S. (2017). The promise of molecular autopsy in forensic pathology practice. *Academic Forensic Pathology, 7*(4), 551-566. https://doi.org/10.23907/2017.047.

143. U.S. Department of Health and Human Services (DHHS). (2018). Report to Congress: Federal activities related to stillbirth, sudden unexpected infant death, and sudden unexplained death in childhood. Retrieved from http://sudc.s3.amazonaws.com/AAA_Amazon/sudcliterature/FinalReportToCongressOnStillbirthMar18.pdf?AWSAccessKeyId=AKIAJYVT3VLDMLUDFRZA&Expires=2145934800&Signature=gGHE9h%2BaHXW4ugSG7sWDKv%2FXvaU%3D.

144. Gulino, S. P., Burns, K., Gunther, W. M., & MacLeod, H. (2018). Improving forensic pathologic investigation of sudden death in the young: Tools, guidance, and methods of cardiovascular dissection from the Sudden Death in the Young Case Registry. *Academic Forensic Pathology, 8*(2), 347-391. https://doi.org/10.1177/1925362118782077.

145. Weinberg, M., Weedn, V. W., Weinberg, S., & Fowler, D. (2013). Characteristics of medical examiner/coroner offices accredited by the National Association of Medical Examiners. *Journal of Forensic Sciences, 58*(5), 1193-1199. https://doi.org/10.1111/1556-4029.12165.

146. Drug Enforcement Administration (DEA), Diversion Control Division, National Forensic Laboratory Information System (NFLIS). (2018). 2017 Medical Examiner/Coroner Office Survey Report. Retrieved from https://www.nflis.deadiversion.usdoj.gov/DesktopModules/ReportDownloads/Reports/NFLIS-MECSurveyReport.pdf.

147. Medicolegal Death Investigation Subcommittee. (2018). Recommendations for medical examiner/coroner drug-related death investigations. Retrieved from https://www.nist.gov/sites/default/files/documents/2018/02/14/osac_mdi.drug_related_death_strategy.2-14-18_1.pdf.

148. Scientific Working Group for Medicolegal Death Investigation (SWG MDI). (2013). Process map – Basic steps in medicolegal death investigation. Retrieved from https://www.nist.gov/sites/default/files/documents/2018/04/25/swgmdi_process_map_-_basic_steps_in_medicolegal_death_investigation.pdf.

149. Christie, C., Baker, C., Cooper, R., Kennedy, P. J., Madras, B., & Bondi, P. (2017). The president's commission on combating drug addiction and the opioid crisis. Retrieved from https://www.whitehouse.gov/sites/whitehouse.gov/files/images/Final_Report_Draft_11-1-2017.pdf.

150. Hedegaard, H., Warner, M., & Miniño, A. M. (2017). Drug overdose deaths in the United States, 1999-2015. Retrieved from https://www.cdc.gov/nchs/data/databriefs/db273.pdf.

151. Hedegaard, H., Warner, M., & Miniño, A. M. (2017). Drug overdose deaths in the United States, 1999-2016. Retrieved from https://www.cdc.gov/nchs/data/databriefs/db294.pdf.

152. Scientific Working Group for Medicolegal Death Investigation (SWG MDI). (2011). Medicolegal autopsy facilities in the United States. Retrieved from Gaithersburg, MD: https://www.nist.gov/sites/default/files/documents/2018/04/24/swgmdi_3_-_medicolegal_autopsy_facilities_in_the_us.pdf.

153. Scientific Working Group for Medicolegal Death Investigation (SWGMDI). (2015). Homepage. Retrieved from https://www.swgmdi.org/.

154. National Institute of Justice (NIJ). (2011). Death investigation: A guide for the scene investigator: Technical update. Retrieved from https://www.ncjrs.gov/pdffiles1/nij/234457.pdf.

155. National Institute of Standards and Technology (NIST). (2019). Forensic science: Medicolegal Death Investigation Subcommittee. Retrieved from https://www.nist.gov/topics/forensic-science/medicolegal-death-investigation-subcommittee.

156. Medicolegal Death Investigation Subcommittee, National Commission on Forensic Science (NCFS). (2017, 2015-10-07). Work products adopted by the commission. Retrieved from https://www.justice.gov/archives/ncfs/work-products-adopted-commission#S4.

157. Morrow, J. B., Ropero-Miller, J. D., Catlin, M. L., Winokur, A. D., Cadwallader, A. B., Staymates, J. L., Williams, S. R., McGrath, J. G., Logan, B. K., McCormick, M. M., Nolte, K. B., Gilson, T. P., Menendez, M. J., & Goldberger, B. A. (2019). The opioid epidemic: Moving toward an integrated, holistic analytical response. *Journal of Analytical Toxicology, 43*(1), 1-9. https://doi.org/10.1093/jat/bky049.

158. System Infrastructure Committee of the Scientific Working Group on Medicolegal Death Investigation (SWGMDI). (2012). Increasing the supply of forensic pathologists in the United States. Retrieved from https://www.nist.gov/sites/default/files/documents/2018/04/24/swgmdi_increasing_the_supply_of_forensic_pathologists_in_the_us.pdf.

159. Accreditation, Certification, Education, and Training Committee of the Scientific Working Group for Medicolegal Death Investigation (SWGMDI). (2014). Certification of medicolegal death investigation personnel. Retrieved from http://www.swgmdi.org/images/ACET3.PRC10.RecommendationCertificationMDIPersonnel.Published.6.5.14.pdf.

160. National Commission on Forensic Science (NCFS). (2015). Views of the Commission: Increasing the number, retention, and quality of board-certified forensic pathologists. National Institute of Standards and Technology (NIST). Retrieved from https://www.justice.gov/archives/ncfs/file/787356/download.

161. Centers for Disease Control and Prevention (CDC), National Center for Health Statistics. (2019). Vital statistics rapid release: Provisional drug overdose death counts. Retrieved from https://www.cdc.gov/nchs/nvss/vsrr/drug-overdose-data.htm.

162. Vestal, C. (2017). Opioid overdoses swamp medical examiners. Retrieved from https://www.pewtrusts.org/en/research-and-analysis/blogs/stateline/2017/07/06/opioid-overdose-deaths-swamp-medical-examiners.

163. Davis, G. G. (2014). National Association of Medical Examiners (NAME) position paper: Recommendations for the investigation, diagnosis, and certification of deaths related to opioid drugs. *Journal of Medical Toxicology, 10(1), 100-106.* https://doi.org/10.1007/s13181-013-0323-x.

164. Medicolegal Death Investigation Subcommittee, National Institute of Standards and Technology (NIST). (2018). Recommendations for medical examiner/coroner drug-related death investigations. Retrieved from https://www.nist.gov/sites/default/files/documents/2018/02/14/osac_mdi.drug_related_death_strategy.2-14-18_1.pdf.

165. Robboy, S. J., Weintraub, S., Horvath, A. E., Jensen, B. W., Alexander, C. B., Fody, E. P., Crawford, J. M., Clark, J. R., Cantor-Weinberg, J., Joshi, M. G., Cohen, M. B., Prystowsky, M. B., Bean, S. M., Gupta, S., Powell, S. Z., Speights, V. O., Gross, D. J., & Black-Schaffer, W. S. (2013). Pathologist workforce in the United States: I. Development of a predictive model to examine factors influencing supply. *Archives of Pathology & Laboratory Medicine, 137*(12), 1723-1732. https://doi.org/10.5858/arpa.2013-0200-OA.

166. Ropero-Miller, J. D., Jones, N. S., LaPorte, G., & McGrath, J. (2018). Final report: Strengthening the medical examiner–coroner system through NIJ-funded programs. National Institute of Justice. https://rti.connectsolutions.com/pvmowt95gx7z/.

167. Infrastructure Committee of the Scientific Working Group on Medicolegal Death Investigation (SWGMDI). (2013). Relationships between pathology departments and medical examiner/coroner offices. Retrieved from http://swgmdi.org/images/si3.prc6.fpsupport.published7.19.13.pdf.

168. Spencer, A., Ross, W. K., & Domen, R. E. (2017). Forensic pathology education in pathology residency: A survey of current practices, a novel curriculum, and recommendations for the future. *Academic Pathology, 4*, 1-10. https://doi.org/10.1177/2374289517719503.

169. Iowa Office of the State Medical Examiner (IOSME). (2015). History of the Iowa state medical examiner. Retrieved from https://iosme.iowa.gov/sites/default/files/documents/2015/09/history_of_the_iosme_0.pdf.

170. Beam, A. (2018). Kentucky seeks relief as autopsy requests surge. *Forensic Magazine.* https://www.forensicmag.com/news/2018/05/kentucky-seeks-relief-autopsy-requests-surge?et_cid=6330027&et_rid=833262759&type=cta&et_cid=6330027&et_rid=833262759&linkid=https%3a%2f%2fwww.forensicmag.com%2fnews%2f2018%2f05%2fkentucky-seeks-relief-autopsy-requests-surge%3fet_cid%3d6330027%26et_rid%3d%%subscriberid%%%26type%3dcta.

171. Maryland Department of Health. (n.d.). OCME educational and training programs. Retrieved from https://health.maryland.gov/ocme/Pages/education-training.aspx.

172. Allegheny County Office of the Chief Medical Examiner. (2019). Medical student rotation and forensic internship program. Retrieved from https://www.alleghenycounty.us/medical-examiner/careers-internship-general.aspx.

173. National Association of Medical Examiners (NAME). (2017). Annual meeting program. Scottsdale, AZ. https://www.thename.org/assets/docs/NAME%202017%20FULL%20PROGRAM.pdf.

174. Maricopa County. (2017). Loan repayment assistance program for medical examiners approved. Press release. Retrieved from https://www.maricopa.gov/CivicAlerts.aspx?AID=340&ARC=825.

175. Wisnia, E., & Brown, T. (2010). California coroner occupation analysis report. Retrieved from https://post.ca.gov/Portals/0/Publications/Coroner.pdf?ver=2019-07-12-131112-150.

176. Orange County Sheriff's Department. (n.d.). California Coroner Training Center. Retrieved from http://www.ocsd.org/divisions/fieldops/coroner/cctc.

177. Accreditation, Certification, Education, and Training Committee of the Scientific Working Group for Medicolegal Death Investigation (SWGMDI). (2012). Report of the minimal educational requirements for medicolegal death investigation system personnel. Retrieved from https://www.nist.gov/sites/default/files/documents/2018/04/24/swgmdi_minimal_educational_requirements_for_mdi_system_personnel.pdf.

178. National Commission on Forensic Science (NCFS). (2015). Recommendation to the Attorney General: Certification of medicolegal death investigators. Retrieved from https://www.justice.gov/archives/ncfs/page/file/788026/download.

179. American Board of Medicolegal Death Investigators (ABMDI). (2019). Welcome to ABMDI. Retrieved from https://abmdi.org/.

180. International Association of Forensic Nurses (IAFN). (2018). The forensic nurse as a death investigator. Retrieved from https://www.forensicnurses.org/page/DeathInvest.

181. Hufft, A., Lynch, V., & Williams, J. (2013). Forensic nurse death investigator education guidelines. Retrieved from https://cdn.ymaws.com/www.forensicnurses.org/resource/resmgr/Education/Nurse_Death_Investigator_Edu.pdf.

182. West Virginia University, John Chambers College of Business and Economics. (2019). FORESIGHT overview. Retrieved from https://business.wvu.edu/centers/forensic-business-studies/foresight.

183. National Association of Medical Examiners (NAME). (n.d.). Inspection and accreditation. Retrieved from https://www.thename.org/inspection-accreditation.

184. International Association of Coroners & Medical Examiners (IAC&ME). (2015). IAC&ME accreditation. Retrieved from https://www.theiacme.com/accreditation.

185. Gill, J. R. (2014). State medical examiner systems, 2013: Staffing, autopsies, strengths, limitations, and needs. *Academic Forensic Pathology, 4*(1), 24-31. https://doi.org/10.23907/2014.004.

186. National Commission on Forensic Science (NCFS). (2015). Recommendation to the Attorney General: Accreditation of medicolegal death investigation offices. Retrieved from https://www.justice.gov/archives/ncfs/page/file/787236/download.

187. Accreditation, Certification, Education, and Training Committee of the Scientific Working Group for Medicolegal Death Investigation (SWGMDI). (2012). Report of the comparison of the NAME and the IAC&ME accreditation standards. National Institute of Standards and Technology (NIST). Retrieved from https://www.nist.gov/sites/default/files/documents/2018/04/24/swgmdi_comparison_of_name_and_the_iacme_accreditation_standards.pdf.

188. ANSI National Accreditation Board (ANAB). (2019). ANAB and NAME form strategic alliance. Retrieved from https://www.anab.org/latest-news/anab-and-name-form-strategic-alliance.

189. Organization of Scientific Area Committees for Forensic Science (OSAC). (2019). OSAC approved standards. National Institute of Standards and Technology (NIST). Retrieved from https://www.nist.gov/topics/forensic-science/organization-scientific-area-committees-osac/osac-registry/osac-approved.

190. System Infrastructure Committee of the Scientific Working Group on Medicolegal Death Investigation (SWGMDI). (2013). Regional medicolegal autopsy and death investigation centers: Construction, staffing, and costs. Retrieved from https://www.swgmdi.org/images/si6.facilityconstruction.published.9-17-13.pdf.

191. Hanzlick, R. L. (2015). The Future of forensic pathology: Is regionalization a key? *Academic Forensic Pathology, 5*(4), 516-525. https://doi.org/10.23907/2015.057.

192. System Infrastructure Committee of the Scientific Working Group on Medicolegal Death Investigation (SWGMDI). (2013). Workplace locations of board certified forensic pathologists in the United States who perform medicolegal autopsies for medical examiner/coroner systems: 2012. National Institute of Standards and Technology (NIST). Retrieved from https://www.nist.gov/sites/default/files/documents/2018/04/25/swgmdi_workplace_locations_of_board_certified_forensic_pathologists_in_the_us_who_perform_medicolegal_autopsies.pdf.

193. SWGMDI Infrastructure Committee. (2012). State Medical Examiner Survey. National Institute of Standards and Technology (NIST). Retrieved from https://www.nist.gov/sites/default/files/documents/2018/04/24/swgmdi_4_-_state_medical_examiner_survey.pdf.

194. Jones, N. S., Ropero-Miller, J. D., Waltke, H., McLeod-Henning, D., Weiss, D., & Barcus, H. (2017). Proceedings of the International Forensic Radiology Research Summit. Amsterdam, the Netherlands. https://www.rti.org/sites/default/files/resources/18169326_International_Forensic_Radiology_Research_Summit_2016.pdf.

195. Lathrop, S. L., & Nolte, K. B. (2016). Utility of postmortem x-ray computed tomography (CT) in supplanting or supplementing medicolegal autopsies. NCJ 249949. NIJ Award Number 2010-DN-BX-K205. Retrieved from https://www.ncjrs.gov/pdffiles1/nij//grants/249949.pdf.

196. Weiss, D., McLeod-Henning, D., & Waltke, H. (2018). Using advanced imaging technologies to enhance autopsy practices. *NIJ Journal, 279*, 1-8. https://www.ncjrs.gov/pdffiles1/nij/250698.pdf.

197. Daly, B., Andrews, S., & O'Donnell, C. (2015). The current and potential future role of postmortem computed tomography in medicolegal death investigation. *Academic Forensic Pathology, 5*(4), 590-602. https://doi.org/10.23907/2015.063.

198. Ali, Z., Daly, B., & Fowler, D. R. (2015). The first use of postmortem 3D computed tomography images as evidence in US criminal courts: A report of four cases. *Academic Forensic Pathology, 5*(4), 650-661. https://doi.org/10.23907/2015.069.

199. Centers for Disease Control and Prevention (CDC). (2019). Enhanced state opioid overdose surveillance. Retrieved from https://www.cdc.gov/drugoverdose/foa/state-opioid-mm.html.

200. U.S. Department of Justice (DOJ), Office of Justice Programs (OJP), Bureau of Justice Assistance (BJA). (2018). Comprehensive opioid abuse site-based program: FY 2018 competitive grant announcement. Retrieved from https://www.bja.gov/funding/COAP18.pdf.

201. Centers for Disease Control and Prevention (CDC). (2019). SUID and SDY case registry. Retrieved from https://www.cdc.gov/sids/case-registry.htm?CDC_AA_refVal=https%3A%2F%2Fwww.cdc.gov%2Fsids%2FCaseRegistry.htm.

202. U.S. Department of Justice (DOJ), Office of Justice Programs (OJP), National Institute of Justice (NIJ). (2017). Solicitation: NIJ FY 2017 Strengthening the medical examiner-coroner system program. Retrieved from https://nij.ojp.gov/sites/g/files/xyckuh171/files/media/document/NIJ-2017-11566.pdf.

203. U.S. Department of Justice (DOJ), Office of Justice Programs (OJP), National Institute of Justice (NIJ). (2018). Solicitation: NIJ FY 2018 Strengthening the medical examiner-coroner system program. Retrieved from https://nij.ojp.gov/sites/g/files/xyckuh171/files/media/document/NIJ-2018-13743.pdf.

204. Research Committee of the Scientific Working Group on Medicolegal Death Investigation (SWGMDI). (2014). Research in forensic pathology/medicolegal death investigation. Retrieved from https://www.nist.gov/sites/default/files/documents/2018/04/25/swgmdi_research_in_forensic_pathology_medicolegal_death_investigation.pdf.

205. Hanzlick, R. L., & Clark, S. (2012). Journal articles authored by forensic pathologists board certified during the years 1985-2010. *Academic Forensic Pathology, 2*(4), 357-369. https://doi.org/10.23907/2012.054.

206. Nolte, K. B. (2004). Research issues in forensic pathology: A survey of academic institutions employing forensic pathologists. *Human Pathology, 35*(5), 532-535. https://doi.org/10.1016/j.humpath.2004.01.010.

207. U.S. Department of Justice (DOJ), Office of Justice Programs (OJP), National Institute of Justice (NIJ). (2019). Research and evaluation in publicly funded forensic laboratories. Retrieved from https://www.nij.gov/topics/forensics/lab-operations/Pages/public-labs-research-solicitation.aspx.

208. National Association of Medical Examiners (NAME). (2015). NAME position statement on forensic pathologist courtroom testimony in out-of-jurisdiction legacy cases. Retrieved from https://name.memberclicks.net/assets/docs/9065536b-fb3d-435e-b987-d254ae91d3eb.pdf.

209. National Center for Fatality Review and Prevention (CFRP). (n.d.). Homepage. Retrieved from https://www.ncfrp.org/.

210. Missouri Department of Social Services. (n.d.). Missouri child fatality review program. Retrieved from https://dss.mo.gov/stat/mcfrp.htm.

211. Virginia Department of Health (VDH). (2019). Fatality review & surveillance programs & reports. Retrieved from http://www.vdh.virginia.gov/medical-examiner/fatality-review-surveillance-programs-reports/.

212. O'Brien, M. (2018). Notes from the Field: Understanding the opioid crisis through data and all-stakeholder reviews. National Institute of Justice (NIJ). Retrieved from https://www.nij.gov/publications/pages/notes-from-the-field-opioid-epidemic-obrien.aspx.

213. Heller, D., Bradley O'Brien, D., Harocopos, A., Hreno, J., Lerner, J., McCoy, E. B., Nolan, M., Phillips Lum, P., Tuazon, E., Parker, C., Kunins, H., & Paone, D. (2014). RxStat: Technical Assistance Manual. Retrieved from http://www.pdmpassist.org/pdf/RxStat.pdf.

214. D.C. Office of the Chief Medical Examiner (OCME). (n.d.). Epidemiology and surveillance reports. Retrieved from https://ocme.dc.gov/publication/epidemiology-and-surveillance-reports#.

215. Committee for the Workshop on the Medicolegal Death Investigation System, & Board on Health Promotion and Disease Prevention. (2003). Medicolegal death investigation system: Workshop summary. National Academies Press. Retrieved from https://www.nap.edu/read/10792/chapter/1#ii.

216. Virginia Department of Health (VDH). (2019). Forensic epidemiology. Retrieved from http://www.vdh.virginia.gov/medical-examiner/forensic-epidemiology/.

217. National Commission on Forensic Science (NCFS). (2016). Recommendation to the Attorney General: Electronic networking of medical examiner and coroner offices in the United States. Retrieved from https://www.justice.gov/archives/ncfs/page/file/787351/download.

218. Levy, B. (2015). The need for informatics to support forensic pathology and death investigation. *Journal of Pathology Informatics. 6*, 32. https://doi.org/10.4103/2153-3539.158907.

219. Prescription Monitoring Program Center of Excellence at Brandeis. (2011). Drug-related deaths in Virginia: Medical examiner use of PMP data. Bureau of Justice Assistance Award 2009-PM-BX-K044. Retrieved from http://www.pdmpassist.org/pdf/Resources/va_medical_examiner_NFF_final.pdf.

220. Prescription Drug Monitoring Program Training and Technical Assistance Center (TTAC), & Institute for Intergovernmental Research (IIR). (2018). Meeting summary. Prescription drug monitoring program and medical examiner/coroner meeting: Building collaboration, Washington, DC. Retrieved from https://www.pdmpassist.org/pdf/Resources/PDMP_ME-C_Meeting_Summary_20190703.pdf.

221. Program set up to help solve cold, missing and unidentified person cases. (2018). *The Shawnee News-Star.* Retrieved from https://www.news-star.com/news/20180816/program-set-up-to-help-solve-cold-missing-and-unidentified-person-cases.

222. U.S. Department of Justice (DOJ), Office of Justice Programs (OJP), Office for Victims of Crime (OVC). (2015). Helping victims of mass violence & terrorism - Planning, response, recovery, and resources. Retrieved from https://www.ovc.gov/pubs/mvt-toolkit/index.html.

223. Hedegaard, H., Miniño, A. M., & Warner, M. (2018). Drug overdose deaths in the United States, 1999-2017. NCHS data brief. Centers for Disease Control and Prevention, National Center for Health Statistics. Retrieved from https://www.cdc.gov/nchs/data/databriefs/db329-h.pdf.

224. Jalal, H., Buchanich, J. M., Roberts, M. S., Balmert, L. C., Zhang, K., & Burke, D. S. (2018). Changing dynamics of the drug overdose epidemic in the United States from 1979 through 2016. *Science, 361*(6408). https://science.sciencemag.org/content/361/6408/eaau1184.abstract.

225. Seth, P., Scholl, L., Rudd, R. A., & Bacon, S. (2018). Overdose deaths involving opioids, cocaine, and psychostimulants—United States, 2015–2016. *Morbidity and Mortality Weekly Report, 67*(12), 349-358. Retrieved from https://www.cdc.gov/mmwr/volumes/67/wr/mm6712a1.htm?s_cid=mm6712a1_w.

226. Drug Enforcement Administration (DEA), Diversion Control Division, National Forensic Laboratory Information System (NFLIS). (2018). NFLIS-Drug 2017 annual report. Retrieved from https://www.nflis.deadiversion.usdoj.gov/DesktopModules/ReportDownloads/Reports/NFLIS-Drug-AR2017.pdf.

227. Drug Enforcement Administration (DEA), Diversion Control Division, National Forensic Laboratory Information System (NFLIS). (2019). NFLIS published reports. Retrieved from https://www.nflis.deadiversion.usdoj.gov/Reports.aspx.

228. Drug Enforcement Administration (DEA), Diversion Control Division, National Forensic Laboratory Information System (NFLIS). (2017). NFLIS brief: Fentanyl, 2001-2015. Retrieved from https://www.nflis.deadiversion.usdoj.gov/DesktopModules/ReportDownloads/Reports/NFLISFentanylBrief2017.pdf.

229. Drug Enforcement Administration (DEA), Diversion Control Division, National Forensic Laboratory Information System (NFLIS). (2016). Special report: Synthetic cannabinoids and synthetic cathinones reported in NFLIS, 2013-2015. Retrieved from https://www.nflis.deadiversion.usdoj.gov/DesktopModules/ReportDownloads/Reports/NFLIS-SR-SynthCannabinoidCathinone.pdf.

230. Drug Enforcement Administration (DEA), Diversion Control Division, National Forensic Laboratory Information System (NFLIS). (2018). NFLIS brief: Fentanyl and fentanyl-related substances reported in NFLIS, 2015-2016. Retrieved from https://www.nflis.deadiversion.usdoj.gov/DesktopModules/ReportDownloads/Reports/11350_R2_NFLIS_Research_Brief_Fentanyl.pdf.

231. U.S. House of Representatives. (2018). Congressional record: Proceedings and debates of the 115th Congress, second session. Washington, DC. Retrieved from https://www.congress.gov/crec/2018/03/22/CREC-2018-03-22-bk2.pdf.

232. Council of Economic Advisers. (2017). The underestimated cost of the opioid crisis. Retrieved from https://www.whitehouse.gov/sites/whitehouse.gov/files/images/The%20Underestimated%20Cost%20of%20the%20Opioid%20Crisis.pdf.

233. Florence, C., Luo, F., Xu, L., & Zhou, C. (2016). The economic burden of prescription opioid overdose, abuse and dependence in the United States, 2013. *Medical Care, 54*(10), 901-906. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5975355/.

234. Ropero-Miller, J. D., & Speaker, P. J. (2019). The hidden costs of the opioid crisis and the implications for financial management in the public sector. Submitted to

Forensic Science International: Synergy. Retrieved from https://www.researchgate.net/publication/334786101_Hidden_costs_of_the_opioid_crisis_Complete.

235. Drug Enforcement Administration (DEA), Diversion Control Division. (n.d.). Title 21 United States Code (USC) Controlled Substances Act: Subchapter I - Control and Enforcement. Retrieved from https://www.deadiversion.usdoj.gov/21cfr/21usc/802.htm.

236. American Society of Crime Laboratory Directors (ASCLD) Opioid Task Force. (2018). Opioid derivatives: Analysis and instrumentation. Retrieved from Garner, NC: https://www.ascld.org/wp-content/uploads/2018/08/OTF-Analysis-and-Instrumentation-7.20.18-V3.pdf.

237. Forensic Sciences at RTI International. (2018). On-demand/online symposium: Current trends in forensic toxicology [Agilent]. Retrieved from https://forensicrti.org/virtual-online-symposium-current-trends-in-forensic-toxicology-agilent/.

238. Scientific Working Group for the Analysis of Seized Drugs (SWGDRUG). (2019). Monographs. Retrieved from http://www.swgdrug.org/monographs.htm.

239. Urbas, A., Schoenberger, T., Corbett, C., Lippa, K., Rudolphi, F., & Robien, W. (2018). NPS Data Hub: A web-based community driven analytical data repository for new psychoactive substances. *Forensic Chemistry, 9*, 76-81. https://doi.org/10.1016/j.forc.2018.05.003.

240. The Center for Forensic Science Research and Education (CFSRE). (2019). NPS discovery. Retrieved from http://www.forensicscienceeducation.org/resources/nps-discovery/.

241. American Society of Crime Laboratory Directors (ASCLD). (n.d.). Opioid Resource Center. Retrieved from https://www.ascld.org/opioid-resource-center/.

242. Center for Behavioral Health Statistics and Quality. (2016). Key substance use and mental health indicators in the United States: Results from the 2015 National Survey on Drug Use and Health. (HHS Publication No. SMA 16-4984, NSDUH Series H-51). https://www.samhsa.gov/data/nsduh/reports-detailed-tables-2015-NSDUH.

243. Forensic Technology Center of Excellence (FTCoE). (2018). Three part online workshop series: Best practices guidance for advancing research initiatives and combatting the synthetic drug epidemic. Sessions 1, 2, and 3: July 17, 18, and 25, 2018. Retrieved from https://forensiccoe.org/webinar/best-practices-synthetic-drug-epidemic/.

244. Drug Enforcement Administration (DEA), Diversion Control Division, National Forensic Laboratory Information System (NFLIS). (2018). 2017 Toxicology Laboratory Survey report. Retrieved from https://www.nflis.deadiversion.usdoj.gov/DesktopModules/ReportDownloads/Reports/NFLIS-2017ToxLabSurveyReport.pdf.

245. Franckowski, R. E. (2013). Authentication of reference materials. Paper presented at the Emerging Trends in Synthetic Drugs Workshop. https://www.nist.gov/sites/default/files/documents/oles/5-Day-2Authentication-of-Standards-DEA-NIST-2013-REF-Franckowski.pdf.

246. Centers for Disease Control and Prevention (CDC). (2019). Emergency preparedness and response: Laboratory Response Network (LRN). Retrieved from https://emergency.cdc.gov/lrn/index.asp.

247. Centers for Disease Control and Prevention (CDC). (2019). Laboratory Response Network for Chemical Threats (LRN-C). Retrieved from https://emergency.cdc.gov/lrn/chemical.asp.

248. Centers for Disease Control and Prevention (CDC), National Center for Environmental Health. (2019). Division of Laboratory Sciences: Traceable opioid material kits to improve laboratory detection of synthetic opioids in the U.S. Retrieved from https://www.cdc.gov/nceh/dls/erb_opioid_kits.html.

249. King, B. S., Musolin, K., & Choi, J. (2013). Evaluation of potential employee exposures during crime and death investigations at a county coroner's office. Centers for Disease Control and Prevention (CDC). Retrieved from https://stacks.cdc.gov/view/cdc/50321.

250. Sisco, E., Najarro, M., & Burns, A. (2018). A snapshot of drug background levels on surfaces in a forensic laboratory. *Forensic Chemistry, 11*, 47-57. https://doi.org/10.1016/j.forc.2018.09.001.

251. Office of National Drug Control Policy (ONDCP). (n.d.). Fentanyl safety recommendations for first responders. Washington, DC: The White House. Retrieved from https://www.whitehouse.gov/ondcp/key-issues/fentanyl/.

252. Howard, J., & Hornsby-Myers, J. (2018). Fentanyls and the safety of first responders: Science and recommendations. Retrieved from https://blogs.cdc.gov/niosh-science-blog/2018/06/26/fentanyls-and-first-responders/.

253. U.S. Department of Justice (DOJ), Office of Public Affairs. (2018). Justice Department announces release of new fentanyl safety video for first responders. Press release. Retrieved from https://www.justice.gov/opa/pr/justice-department-announces-release-new-fentanyl-safety-video-first-responders.

254. Chiu, S., Hornsby-Myers, J., & Trout, D. (2018). Evaluation of Law Enforcement Officers' Potential Occupational Exposure to Illicit Drugs — Virginia. National Institute for Occupational Safety and Health (NIOSH), Centers for Disease Control and Prevention (CDC). Retrieved from https://www.cdc.gov/niosh/hhe/reports/pdfs/2018-0113-3325.pdf.

255. Chiu, S., Hornsby-Myers, J., & Trout, D. (2018). Evaluation of a New Hampshire law enforcement officer's unintentional occupational exposure to illicit drugs. Centers for Disease Control and Prevention (CDC). Retrieved from https://stacks.cdc.gov/view/cdc/58851.

256. Chiu, S., Hornsby-Myers, J., & Trout, D. (2018). Evaluation of occupational exposures to illicit drugs during a law enforcement and emergency medical services response. Centers for Disease Control and Prevention (CDC), National Institute for Occupational Safety and Health (NIOSH). Retrieved from https://www.cdc.gov/niosh/hhe/reports/pdfs/2018-0083-3332.pdf.

257. Jackson, D., Chiu, S., & Hornsby-Myers, J. (2018). Evaluation of law enforcement officers' occupational exposure to illicit drugs. Centers for Disease Control and Prevention (CDC), National Institute for Occupational Safety and Health (NIOSH). Retrieved from https://www.cdc.gov/niosh/hhe/reports/pdfs/2018-0118-3331.pdf.

258. Logan, B. K., D'Orazio, A. L., Mohr, A. L. A., Limoges, J. F., Miles, A. K., Scarneo, C. E., Kerrigan, S., Liddicoat, L. J., Scott, K. S., & Huestis, M. A. (2017).

Recommendations for toxicological investigation of drug-impaired driving and motor vehicle fatalities — 2017 update. *Journal of Analytical Toxicology, 42*(2), 63-68. https://doi.org/10.1093/jat/bkx082.

259. Hedlund, J. (2018). Drug-impaired driving: Marijuana and opioids raise critical issues for states. Washington, DC: Governors Highway Safety Association. Retrieved from https://www.ghsa.org/resources/DUID18.

260. Drug Enforcement Administration (DEA). (n.d.). High Intensity Drug Trafficking Areas (HIDTAs). Retrieved from https://www.dea.gov/hidta.

261. Beeson, J. (2018). ODMAP: Notes from the Field: A digital tool to track and analyze overdoses. Overdose Protection Mapping Application. National Institute of Justice (NIJ). Retrieved from https://nij.gov/publications/Pages/notes-from-the-field-opioid-epidemic-beeson.aspx.

262. Forensic Technology Center of Excellence (FTCoE). (2018). Landscape study of field portable devices for presumptive drug testing. Retrieved from https://rti.connectsolutions.com/alsfpd/.

263. Sisco, E., Verkouteren, J., Staymates, J., & Lawrence, J. (2017). Rapid detection of fentanyl, fentanyl analogues, and opioids for on-site or laboratory based drug seizure screening using thermal desorption DART-MS and ion mobility spectrometry. *Forensic Chemistry, 4*, 108-115. https://doi.org/10.1016/j.forc.2017.04.001.

264. Florida International University (FIU) National Forensic Science Technology Center. (2019). Field Investigation Drug Officer (FIDO). Retrieved from http://www.nfstc.org/past-performance/field-investigation-drug-officer-fido/.

265. American Society of Crime Laboratory Directors (ASCLD). (2019). Industrial hemp and its impact to forensic laboratories. Retrieved from https://www.ascld.org/wp-content/uploads/2019/02/ASCLD-Statement-on-Hemp.pdf.

266. Tuohy, D. (2018). N.H. crime lab reduces backlog after marijuana decriminalization put in effect. New Hampshire Public Radio. Retrieved from https://www.nhpr.org/post/nh-crime-lab-reduces-backlog-after-marijuana-decriminalization-put-effect#stream/0.

267. U.S. Department of Justice (DOJ), Office of Justice Programs (OJP), National Institute of Justice (NIJ). (2018). Forensic Science Research and Development Technology Working Group: Operational Requirements. Retrieved from https://www.nij.gov/topics/forensics/Pages/forensic-operational-requirements.aspx.

268. U.S. Department of Justice (DOJ), Office of Justice Programs (OJP), National Institute of Justice (NIJ). (2015). Optimal extraction methods of THC from infused products. NIJ Award 2015-DN-BX-K028. Retrieved from https://nij.ojp.gov/funding/awards/2015-dn-bx-k028.

269. U.S. Department of Justice (DOJ), Office of Justice Programs (OJP), National Institute of Justice (NIJ). (2017). Development of matrix matched quality control materials and sample preparation techniques for the analysis of marijuana infused products and their application to edible testing. NIJ Award 2017-R2-CX-0029. https://external.ojp.usdoj.gov/selector/awardDetail?awardNumber=2017-R2-CX-0029&fiscalYear=2017&applicationNumber=2017-90587-VA-DN&programOffice=NIJ&po=NIJ.

270. Goodison, S. E., Davis, R. C., & Jackson, B. A. (2015). Digital evidence and the U.S. criminal justice system. RAND Corporation, Police Executive Research Forum (PERF), RTI International, and University of Denver. NIJ Award 2013-MU-CX-K003. Retrieved from https://www.rand.org/pubs/research_reports/RR890.html.

271. OSAC Task Group on Digital/Multimedia Science. (2018). A framework for harmonizing forensic science practices and digital/multimedia evidence. National Institute of Standards and Technology (NIST). Retrieved from https://www.nist.gov/sites/default/files/documents/2018/01/10/osac_ts_0002.pdf.

272. U.S. Department of Justice (DOJ), Office of Justice Programs (OJP), Bureau of Justice Statistics (BJS). (2018). Pilot study of state and federal digital evidence laboratories, [United States], 2014 (ICPSR 37055). https://doi.org/10.3886/ICPSR37055.v1.

273. Police Executive Research Forum (PERF). (2018). New national commitment required: The changing nature of crime and criminal investigations. Retrieved from https://www.policeforum.org/assets/ChangingNatureofCrime.pdf.

274. Amoroso, E. (2019). Cybersecurity: A call to action for police executives. *Police Chief* (magazine). Alexandria, VA: International Association of Chiefs of Police (IACP). Retrieved from http://www.policechiefmagazine.org/cybersecurity-a-call-to-action-for-police-executives/.

275. Law Enforcement Cyber Center. (2015). Cyber report card - Police executives. Alexandria, VA: International Association of Chiefs of Police (IACP). Retrieved from http://www.iacpcybercenter.org/wp-content/uploads/2015/09/LECC_Cyber_Report_Card_v10_1509.pdf.

276. Law Enforcement Cyber Center. (2017). Managing cybersecurity risk: A law enforcement guide. Alexandria, VA: International Association of Chiefs of Police (IACP). Retrieved from http://www.iacpcybercenter.org/wp-content/uploads/2015/04/Managing_Cybersecurity_Risk_2017.pdf.

277. U.S. Department of Homeland Security (DHS). (n.d.). Cyber incident reporting: A unified message for reporting to the federal government. Retrieved from https://www.dhs.gov/sites/default/files/publications/Cyber%20Incident%20Reporting%20United%20Message.pdf.

278. U.S. Department of Homeland Security (DHS). (n.d.). Cyber incident response. Retrieved from https://www.dhs.gov/cisa/cyber-incident-response.

279. U.S. Department of Justice (DOJ), Office of the Inspector General (OIG). (2015). Audit of the Federal Bureau of Investigation's Philadelphia Regional Computer Forensic Laboratory, Radnor, Pennsylvania. Retrieved from https://oig.justice.gov/reports/2015/a1514.pdf.

280. U.S. Department of Defense Cyber Crime Center (DC3). (n.d.). Technical solutions. Retrieved from https://www.dc3.mil/technical-solutions#tools-validations.

281. Software Quality Group. (2019). Computer Forensics Tool Testing Program (CFTT). Retrieved from https://www.nist.gov/itl/ssd/software-quality-group/computer-forensics-tool-testing-program-cftt.

282. Software Quality Group. (2019). CFTT Federated Testing Project. Retrieved from https://www.nist.gov/itl/ssd/software-quality-group/computer-forensics-tool-testing-program-cftt/cftt-federated-testing.

283. National Institute of Standards and Technology (NIST). (2019). The CFReDS Project. Retrieved from https://www.cfreds.nist.gov/.

284. National Institute of Standards and Technology (NIST). (2018). Drone forensics gets a boost with new data on NIST website. Retrieved from https://www.nist.gov/news-events/news/2018/06/drone-forensics-gets-boost-new-data-nist-website.

285. National Institute of Standards and Technology (NIST). (2017). National Software Reference Library (NSRL). Retrieved from https://www.nist.gov/software-quality-group/national-software-reference-library-nsrl.

286. National Institute of Standards and Technology (NIST). (2018). Database of software "fingerprints" expands to include mobile apps. Retrieved from https://www.nist.gov/news-events/news/2016/12/database-software-fingerprints-expands-include-mobile-apps.

287. ANSI-ASQ National Accreditation Board (ANAB). (2019). Directory of accredited organizations. Retrieved from http://search.anab.org/.

288. American Association for Laboratory Accreditation (A2LA). (2017). Search A2LA directory of accredited organizations. Retrieved from https://portal.a2la.org/search/.

289. Scientific Working Group on Digital Evidence (SWGDE). (2017). SWGDE framework of a quality management system for digital and multimedia evidence forensic science service providers. Retrieved from https://www.swgde.org/documents/Current%20Documents/SWGDE%20Framework%20of%20a%20Quality%20Management%20System%20for%20Digital%20and%20Multimedia%20Evidence%20Forensic%20Science%20Service%20Providers.

290. Scientific Working Group on Digital Evidence (SWGDE). (2017). SWGDE overview of the accreditation process for digital and multimedia forensic labs. Retrieved from https://www.swgde.org/documents/Current%20Documents/SWGDE%20Overview%20of%20the%20Accreditation%20Process%20for%20Digital%20and%20Multimedia%20Forensic%20Labs.

291. McGrath, J., Emerson, J. J., Hutchens, A., Schilling, C., Snyder, C., & Stoiloff, S. (2018). What every chief needs to know about quality management of forensic units for professional policing. Paper presented at the International Association of Chiefs of Police (IACP) Conference, Orlando, FL. https://plan.core-apps.com/iacp2018/event/2f717394f6594a422becdcebe6dfb766.

292. U.S. Department of Justice (DOJ), Office of Justice Programs (OJP), National Institute of Justice (NIJ). (2018). Resources provided for IACP 2018 panel: "What every chief needs to know about quality management of forensic units for professional policing." Retrieved from https://static.coreapps.net/iacp2018/handouts/6aed20f9-3592-4e94-ac01-02270510f605_1.pdf.

293. Stapleton, C. (2016). Feds say drug dealer sold fentanyl that killed Wellington man, 22. *The Palm Beach Post*. Retrieved from https://www.mypalmbeachpost.com/news/crime–law/feds-say-drug-dealer-sold-fentanyl-that-killed-wellington-man/FeRkVwndg8WRelKpEPr1eJ/.

294. Erickson, B. (2016). Jury finds drug dealer guilty in sale of fentanyl that killed addict. *South Florida Sun Sentinel*. Retrieved from http://www.sun-sentinel.com/local/palm-beach/fl-fentanyl-death-case-jury-20160808-story.html.

295. Speaker, P. J. (2019). The jurisdictional return on investment from processing the backlog of untested sexual assault kits. *Forensic Science International: Synergy, 1*, 18-23. https://doi.org/10.1016/j.fsisyn.2019.02.055.

296. Waltke, H., & Ames, B. (2017). Uniting to solve sexual assault crimes. National Institute of Justice (NIJ). Retrieved from https://www.nij.gov/topics/law-enforcement/investigations/sexual-assault/pages/uniting-to-solve-sexual-assault-crimes.aspx.

297. U.S. Department of Justice (DOJ), Office of Justice Programs (OJP), National Institute of Justice (NIJ). (2019). Sexual Assault Forensic Evidence-Inventory, Tracking, and Reporting Program Grant Program. Retrieved from https://www.nij.gov/topics/forensics/lab-operations/Pages/safe-itr.aspx.

298. U.S. Department of Justice (DOJ), Office of Justice Programs (OJP), Bureau of Justice Assistance (BJA). (2019). The Sexual Assault Kit Initiative (SAKI). Retrieved from https://sakitta.org/.

299. Faraco, C. C., & LaPorte, G. (2018). National Institute of Justice investing in innovation for the identification, collection, and analysis of sexual assault evidence. *Forensic Science Review, 30*(2), 95-99. Retrieved from http://forensicsciencereview.com/Abstract/30(2)-(R&C)%20Full%20text.pdf.

300. Peterson, J., Johnson, D., Herz, D., Graziano, L., & Oehler, T. (2012). Sexual assault kit backlog study. NIJ Award Number 2006-DN-BX-0094. NCJ 238500. Retrieved from https://www.ncjrs.gov/pdffiles1/nij/grants/238500.pdf.

301. U.S. Department of Justice (DOJ), Office of Justice Programs (OJP), National Institute of Justice (NIJ). (2017). National best practices for sexual assault kits: A multidisciplinary approach. Retrieved from https://www.ncjrs.gov/pdffiles1/nij/250384.pdf.

302. Gamette, M. J. (2018). Promoting justice for victims of crime: Examining the federal investment in DNA analysis. Washington, DC: U.S. Senate Judiciary Committee. Retrieved from https://www.judiciary.senate.gov/imo/media/doc/07-18-18%20Gamette%20Testimony.pdf.

303. Strom, K. J., Hendrix, J. A., Parish, W. J., & Melton, P. (2017). Efficiency in processing sexual assault kits in crime laboratories and law enforcement agencies. NIJ Award Number 2013-NE-BX-0006. NCJ 250682. Retrieved from https://www.ncjrs.gov/pdffiles1/nij/grants/250682.pdf.

304. Wang, C., & Wein, L. M. (2018). Analyzing approaches to the backlog of untested sexual assault kits in the U.S.A. *Journal of Forensic Science, 63*(4), 1110-1121. https://doi.org/10.1111/1556-4029.13739.

305. Doleac, J. L. (2017). The effects of DNA databases on crime. *American Economic Journal: Applied Economics, 9*(1), 165-201. https://doi.org/10.1257/app.20150043.

306. Tegner Anker, A. S., Doleac, J. L., & Landersø, R. (2018). The effects of DNA databases on the deterrence and detection of offenders. The Rockwool Foundation. Retrieved from https://www.rockwoolfonden.dk/app/uploads/2018/04/RFF-Study-Paper-128_The-effects-of-DNA-databases-on-the-deterrence-and-detection-of-offenders-1.pdf.

307. Violence Against Women Reauthorization Act of 2013, Pub. L. No. 113-4 (2013). Retrieved from https://www.congress.gov/bill/113th-congress/senate-bill/47.

308. Sexual Assault Kit Initiative (SAKI). (2018). SAKI grantees sites. Retrieved from https://www.sakitta.org/sakisites/.

309. U.S. Department of Justice (DOJ), Office of Justice Programs (OJP), National Institute of Justice (NIJ). (2018). DNA Capacity Enhancement and Backlog Reduction (CEBR) Program. Retrieved from https://www.nij.gov/topics/forensics/lab-operations/evidence-backlogs/pages/backlog-reduction-program.aspx.

310. Crouse, C. A. (2012). Improving evidence screening efficiency using a biological processing laboratory. NIJ Award Number 2009-DN-BX-K261. NCJ 240203. Retrieved from https://www.ncjrs.gov/pdffiles1/nij/grants/240203.pdf.

311. Montana Department of Justice. (n.d.). Montana SAKI Project. BJA Award Number 2016-AK-BX-K015. Retrieved from https://dojmt.gov/enforcement/specialservices/saki/.

312. Oregon Secretary of State, Oregon Audits Division. (2018). Oregon State Police – Forensic Division has taken appropriate steps to address Oregon's sexual assault kit testing backlog. Retrieved from https://sos.oregon.gov/audits/Documents/2018-16.pdf.

313. Campbell, R., Bybee, D., Ford, J. K., & Patterson, D. (2008). Systems change analysis of SANE programs: Identifying the mediating mechanisms of criminal justice system impact. NIJ Award Number 2005-WG-BX-0003. NCJ 226497. Retrieved from https://www.ncjrs.gov/pdffiles1/nij/grants/226497.pdf.

314. Meunier-Sham, J., & Re, C. (2018). The National TeleNursing Center: Transforming care for sexual assault patients, providers and communities. Forensic Healthcare Online. Paper presented at the Office for Victims of Crime, Washington, DC. https://www.forensichealth.com/2018/08/15/the-national-telenursing-center-transforming-care-for-sexual-assault-patients-providers-and-communities/.

315. Briody, M. (2002). The effects of DNA evidence on sexual offence cases in court. *Current Issues in Criminal Justice, 14*(2), 159-181. https://doi.org/10.1080/10345329.2002.12036257.

316. Waltke, H., LaPorte, G., Weiss, D., Schwarting, D., Nguyen, M., & Scott, F. (2017). Sexual assault cases: Exploring the importance of non-DNA forensic evidence. *NIJ Journal, 279*. Retrieved from https://www.nij.gov/journals/279/Pages/non-dna-evidence-in-sexual-assault-cases.aspx.

317. Morgan, R. E., & Kena, G. (2018). Criminal victimization, 2016: Revised. Bureau of Justice Statistics. Bulletin. NCJ 252121. Retrieved from https://www.bjs.gov/content/pub/pdf/cv16.pdf.

318. Forensic Technology Center of Excellence (FTCoE). (2019). In-brief report series: Beyond DNA — Sexual assault investigations. Retrieved from https://forensiccoe.org/beyond-dna-reports-sexual-assault-reform/.

319. Rosay, A. B. (2016). Violence against American Indian and Alaska Native women and men: 2010 findings from the National Intimate Partner and Sexual Violence Survey. Research Report. Retrieved from https://www.ncjrs.gov/pdffiles1/nij/249736.pdf.

320. U.S. Department of Justice (DOJ), Office of Justice Programs (OJP), National Institute of Justice (NIJ). (2018). Tribal crime and justice. Retrieved from https://nij.gov/topics/tribal-justice/Pages/welcome.aspx.

321. Crossland, C., Palmer, J., & Brooks, A. (2013). NIJ's program of research on violence against American Indian and Alaska Native women. *Violence Against Women, 19*(6), 771-790. https://doi.org/10.1177/1077801213494706.

322. U.S. Department of Justice (DOJ). (2011). Indian Health Care Improvement Act. Retrieved from https://www.justice.gov/sites/default/files/tribal/legacy/2014/02/06/ihia-pdmp-rpt-to-congress.pdf.

323. Griffith, J. G. (2014). Too many gaps, too many fallen victims: Protecting American Indian women from violence on tribal lands. *University of Pennsylvania Journal of International Law, 36*, 785. Retrieved from http://scholarship.law.upenn.edu/cgi/viewcontent.cgi?article=1896&context=jil.

324. Juraska, A., Wood, L., Giroux, J., & Wood, E. (2014). Sexual assault services coverage on Native American land. *Journal of Forensic Nursing, 10*(2), 92-97. https://journals.lww.com/forensicnursing/Fulltext/2014/04000/Sexual_Assault_Services_Coverage_on_Native.6.aspx.

325. The National Coordination Committee on the American Indian/Alaska Native Sexual Assault Nurse Examiner-Sexual Assault Response Team Initiative. (2014). Report to the U.S. Attorney General on improving federal agency response to sexual violence in tribal nations: Issues and recommendations. Washington, DC: U.S. Department of Justice (DOJ), Office of Justice Programs (OJP), Office for Victims of Crime (OVC): Retrieved from https://ojp.gov/ovc/AIANSane-Sart/pdf/NCC_June2014_FinalReport_508.pdf.

326. Tribal Tribune. (2018). New law aims to shed light on missing and murdered indigenous women. Nesplemen, WA: *Tribal Tribune*. Retrieved from www.tribaltribune.com/news/article_c797c802-39ad-11e8-9c5d-e33133bc6574.html.

327. Office for Victims of Crime (OVC). (2013). Vision 21 transforming victim services, final report. NCJ 239957. Retrieved from https://ovc.ncjrs.gov/vision21/pdfs/Vision21_Report.pdf.

328. U.S. Government Accountability Office (GAO). (2011). Indian Health Service: Continued efforts needed to help strengthen response to sexual assaults and domestic violence. Retrieved from https://www.gao.gov/new.items/d1229.pdf.

329. Bachman, R., Zaykowski, H., Kallmyer, R., Poteyeva, M., & Lanier, C. (2008). Violence against American Indian and Alaska Native women and the criminal justice response: What is known. NCJ 223691. Retrieved from https://www.ncjrs.gov/pdffiles1/nij/grants/223691.pdf.

330. Fairchild, D. G., Fairchild, M. W., & Stoner, S. (1998). Prevalence of adult domestic violence among women seeking routine care in a Native American health care facility. *American Journal of Public Health, 88*(10), 1515-1517. https://doi.org/10.2105/AJPH.88.10.1515.

331. Oetzel, J., & Duran, B. (2004). Intimate partner violence in American Indian and/or Alaska Native communities: a social ecological framework of determinants and interventions. *American Indian and Alaska Native Mental Health Research: The Journal of the National Center, 11*(3), 49-68. Retrieved from https://eric.ed.gov/?id=EJ684079.

332. Robin, R. W., Chester, B., & Rasmussen, J. K. (1998). Intimate violence in a Southwestern American Indian tribal community. *Cultural Diversity and Mental Health, 4*(4), 335. http://dx.doi.org/10.1037/1099-9809.4.4.335.

333. US v. Lamott, No. 15-30012, 831 1153 (Court of Appeals, 9th Circuit 2016). Retrieved from https://scholar.google.com/scholar_case?case=16287414281375652373&hl=en&as_sdt=6&as_vis=1&oi=scholarr.

334. Greer, B. T. (2013). Hiding behind tribal sovereignty: Rooting out human trafficking in Indian Country. *Journal of Gender, Race & Justice, 16*(2), 453. Retrieved from https://heinonline.org/HOL/LandingPage?handle=hein.journals/jgrj16&div=19&id=&page=.

335. U.S. Department of the Interior (DOI), Bureau of Indian Affairs (BIA). (n.d.). Frequently asked questions. Retrieved from https://www.bia.gov/frequently-asked-questions.

336. United States Census Bureau. (n.d.). National geographic tallies. Retrieved from https://www.census.gov/geographies/reference-files/time-series/geo/tallies.html.

337. Norris, T., Vines, P. L., & Hoeffel, E. M. (2012). The American Indian and Alaskan Native population: 2010. Retrieved from https://www.census.gov/prod/cen2010/briefs/c2010br-10.pdf.

338. Crimes and Criminal Procedure, 18, United States Code, 2006 Edition, Supplement 5, Title 18 § 1152 (2011 January 3. 2012). Retrieved from https://www.govinfo.gov/app/details/USCODE-2011-title18/USCODE-2011-title18-partI-chap53-sec1152/summary.

339. Crimes and Criminal Procedure, 18, United States Code, 2006 Edition, Supplement 5, Title 18 § 1153 (2011). Retrieved from https://www.govinfo.gov/app/details/USCODE-2011-title18/USCODE-2011-title18-partI-chap53-sec1153.

340. Ogden, D. W. (2010). Memorandum for United States attorneys with districts containing Indian Country: Indian Country Law Enforcement Initiative. Retrieved from https://www.justice.gov/archives/dag/memorandum-united-states-attorneys-districts-containing-indian-country.

341. National Archives and Records Administration, Office of the Federal Register. (2014). Federal Register, 79(239). https://www.govinfo.gov/content/pkg/FR-2014-12-12/pdf/2014-28268.pdf.

342. Strategic Application International (SAI). (2017). PL280: Training program for enhanced collaborative law enforcement. Retrieved from http://pl280.com/.

343. Strategic Application International (SAI). (2017). What is Public Law 280. Retrieved from http://pl280.com/learning-modules/what-is-public-law-280/.

344. Strategic Application International (SAI). (2018). COPS tribal Public Law 280 policing partnerships. Retrieved from http://sai-dc.com/cops-pl280/.

345. Lynch, L. E. (2016). Memorandum for all United States Attorneys: Recommendations of the National Coordination Committee on the AI/AN SANE-SART Initiative for improving federal response to sexual violence in Indian Country. Washington, DC: U.S. Department of Justice (DOJ). Retrieved from https://www.justice.gov/tribal/page/file/922801/download.

346. U.S. Department of Justice (DOJ), Office of Justice Programs (OJP), National Institute of Justice (NIJ). (2019). Missing person's cases: New NamUs data fields. *News From NIJ: Policing & Law Enforcement*. Washington, DC. Retrieved from https://www.justice.gov/file/1130556/download.

347. Addington, C. (2019). *Statement of Charles Addington, Director, Office of Justice Services, Bureau of Indian Affairs, United States Department of the Interior, before the Senate Committee on Indian Affairs*. Retrieved from https://www.indian.senate.gov/sites/default/files/6.19.19%20Addington%20Statement%20for%20Legislative%20Hearing%20%28FINAL%29.pdf.

348. Addington, C. (2018). *Testimony of Charles Addington, Director–Office of Justice Services, Bureau of Indian Affairs, before the Committee on Indian Affairs, United States Senate hearing on "Missing and murdered: Confronting the silent crisis in Indian Country."* U.S. Department of the Interior (DOI), Bureau of Indian Affairs (BIA). Retrieved from https://www.indian.senate.gov/sites/default/files/BIA%20Addington%20SCIA%20crime%20hearing.%20Missing%20and%20Murdered%20OMB%20cleared%20Final%20%284%29.pdf.

349. U.S. Department of the Interior (DOI), Bureau of Indian Affairs (BIA). (2019). Interior holds listening session with tribal partners on reclaiming native communities. Press release. Retrieved from https://www.bia.gov/as-ia/opa/online-press-release/interior-holds-listening-session-tribal-partners-reclaiming-native.

350. U.S. Department of Justice (DOJ), Office of Justice Programs (OJP), National Institute of Justice (NIJ). (2018). Native Student Travel Scholarship Program: Connecting science to crime and justice. Retrieved from https://nij.gov/topics/tribal-justice/Pages/native-student-travel-scholarships.aspx?utm_source=facebook&utm_medium=social-media&utm_campaign=adhoc&utm_term=native-scholarships.

351. Joshi, S., Weiser, T., & Warren-Mears, V. (2018). Drug, opioid-involved, and heroin-involved overdose deaths among American Indians and Alaska Natives — Washington, 1999-2015. Centers for Disease Control and Prevention (CDC). Retrieved from https://www.cdc.gov/mmwr/volumes/67/wr/mm6750a2.htm.

352. Drug Enforcement Administration (DEA). (2017). Drug Enforcement Administration collects record number of unused pills as part of its 14th prescription drug take back day. Press release. Retrieved from https://www.dea.gov/press-releases/2017/11/07/drug-enforcement-administration-collects-record-number-unused-pills-0.

353. Indian Health Service (IHS). Prescription drug monitoring programs. Retrieved from https://www.ihs.gov/painmanagement/monitoring/prescriptiondrug/.

354. U.S. Department of Justice (DOJ). (n.d.). Human factors. Retrieved from https://www.justice.gov/archives/ncfs/human-factors.

355. Dror, I. E., Charlton, D., & Péron, A. E. (2006). Contextual information renders experts vulnerable to making erroneous identifications. *Forensic Science International, 156*(1), 74-78. https://doi.org/10.1016/j.forsciint.2005.10.017.

356. Dror, I., & Rosenthal, R. (2008). Meta-analytically quantifying the reliability and biasability of forensic experts. *Journal of Forensic Sciences, 53*(4), 900-903. https://doi.org/10.1111/j.1556-4029.2008.00762.x.

357. Dror, I. E. (2017). Human expert performance in forensic decision making: seven different sources of bias. *Australian Journal of Forensic Sciences, 49*(5), 541-547. https://doi.org/10.1080/00450618.2017.1281348.

358. Boehm-Davis, D., & Gische, M. (2011). Human factors in latent print examination. Paper presented at the NIJ Conference, Washington, DC. https://nij.gov/multimedia/presenter/presenter-nijconf2011-human-factors/Pages/welcome.aspx; https://www.nij.gov/multimedia/presenter/presenter-nijconf2011-human-factors/pages/presenter-nijconf2011-human-factors.aspx.

359. U.S. Department of Justice (DOJ), Office of Justice Programs (OJP), National Institute of Justice (NIJ). (2012). Effects of human factors on the accuracy of fingerprint analysis. Retrieved from https://www.nij.gov/topics/forensics/evidence/impression/Pages/human-factors.aspx.

360. Expert Working Group on Human Factors in Latent Print Analysis. (2012). Latent print examination and human factors: Improving the practice through a systems approach. Retrieved from https://nvlpubs.nist.gov/nistpubs/ir/2012/NIST.IR.7842.pdf.

361. Vanderkolk, J. R., Swofford, H., Busey, T., & Emerick, B. (2015). The impact of fatigue on latent print examinations as revealed by behavioral and eye gaze testing. Retrieved from https://www.rti.org/sites/default/files/resources/iptes_conference_proceedings.pdf.

362. Merlino, M. L. (2015). Validity, reliability, accuracy, and bias in forensic signature identification. Retrieved from https://www.ncjrs.gov/pdffiles1/nij/grants/248565.pdf.

363. National Institute of Standards and Technology (NIST). (2018). Forensic handwriting examination and human factors. Retrieved from https://www.nist.gov/programs-projects/forensic-handwriting-examination-and-human-factors.

364. Busey, T., & Eldridge, H. (2016). Just Science: Just human factors. Podcast. Forensic Technology Center of Excellence (FTCoE). Retrieved from https://forensiccoe.org/episode-two/.

365. Dror, I. E. (2013). Practical solutions to cognitive and human factor challenges in forensic science. *Forensic Science Policy & Management: An International Journal, 4*(3-4), 105-113. https://doi.org/10.1080/19409044.2014.901437.

366. Morris, J. (2015). Addressing cognitive bias in forensic examinations. Paper presented at the 2015 Impression, Pattern, and Trace Evidence Symposium. https://www.rti.org/sites/default/files/resources/iptes_conference_proceedings.pdf.

367. U.S. Department of Homeland Security (DHS). (2015). 2015 National preparedness goal. Retrieved from https://www.fema.gov/media-library/assets/documents/25959.

368. U.S. Department of Homeland Security (DHS). (2019). National incident management system. Retrieved from https://www.fema.gov/national-incident-management-system.

369. U.S. Department of Homeland Security (DHS). (2013). NIMS intelligence/investigations function guidance and field operations guide. Retrieved from https://www.fema.gov/media-library/assets/documents/84807.

370. Federal Emergency Management Agency (FEMA), Emergency Management Institute. (2015). National Incident Management System (NIMS). Retrieved from https://training.fema.gov/nims/.

371. Federal Emergency Management Agency (FEMA), National Training and Education Division. (2019). Winter 2019 TPP Times. Retrieved from https://www.firstrespondertraining.gov/drupal/sites/default/files/TPP%20Times%20-%20Winter%202019%20Final%2020March2019.pdf.

372. Clandestine Laboratory Investigators Association (C.L.I.A.). (n.d.). Homepage. Retrieved from https://clialabs.com/.

373. U. S. Department of Labor (DOL). (2013). Hazardous waste operations and emergency response. *OSHA* 1910.120. Retrieved from https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.120.

374. Department of Homeland Security (DHS), Federal Emergency Management Agency (FEMA). (2018). Core capabilities. Retrieved from https://www.fema.gov/core-capabilities.

375. U.S. Department of Health and Human Services (DHHS), Office of the Assistant Secretary for Preparedness and Response. (2017). Disaster mortuary operational response teams. Public Health Emergency. Retrieved from http://www.phe.gov/Preparedness/responders/ndms/ndms-teams/Pages/dmort.aspx.

376. Wolf, L. A. (2014). North Carolina Laboratory System Improvement Program: Assessment summary. Retrieved from https://www.aphl.org/programs/quality_systems/performance/Documents/LSIP_2014Sept_NC-PHL-Assessment-Report.pdf.

377. Federal Bureau of Investigation (FBI), Office for Victim Assistance (OVA), & National Transportation Safety Board (NTSB), Transportation Disaster Assistance Division. (n.d.). Mass fatality incident family assistance operations: Recommended strategies for local and state agencies. Retrieved from https://www.ntsb.gov/tda/tdadocuments/mass%20fatality%20incident%20family%20assistance%20operations.pdf.

378. Fudenberg, J. (2016). Medicolegal death investigation: Just planning for the aftermath of a mass shooting. Podcast. Retrieved from https://forensiccoe.org/js6-e4/.

379. National Commission on Forensic Science (NCFS). (2016). Recommendation to the Attorney General: National Disaster Call Center. Retrieved from https://www.justice.gov/archives/ncfs/page/file/880261/download.

380. Centers for Disease Control and Prevention (CDC), National Vital Statistics System (NVSS). (2017). A reference guide for certification of deaths in the event of a natural, human-induced, or chemical/radiological disaster. Retrieved from https://www.cdc.gov/nchs/data/nvss/vsrg/vsrg01.pdf.

381. Ropero-Miller, J. (2016). Federal investment in forensic science research and development: Landscape study. Retrieved from https://rti.connectsolutions.com/p16xm3610wr.

382. National Science Foundation (NSF). (n.d.). IUCRC: Industry-University Cooperative Research Centers Program. Retrieved from https://www.nsf.gov/eng/iip/iucrc/home.jsp.

383. National Science Foundation (NSF), Center for Advanced Research in Forensic Science (CARFS). (2017). Industry-University Cooperative Research Centers Program. Retrieved from http://www.iucrc.org/center/center-advanced-research-forensic-science.

384. Almirall, J. R. (2019). CARFS Center Director report to the National Science Foundation (NSF) and to the CARFS Industry Advisory Board (IAB). Paper presented at the IAB Meeting.

385. U.S. Department of Justice (DOJ), Office of Justice Programs (OJP), National Institute of Justice (NIJ). (2018). Notice regarding the solicitation "Research and development in forensic science for criminal justice purposes." Retrieved from https://nij.gov/funding/Documents/solicitations/NIJ-2018-13600.pdf.

386. U.S. Department of Justice (DOJ), Office of Justice Programs (OJP), National Institute of Justice (NIJ). (2018). Forensic Science Research and Development Technology Working Group: Operational requirements. Retrieved from https://www.nij.gov/topics/forensics/Pages/forensic-operational-requirements.aspx.

387. National Institute of Standards and Technology (NIST). (2018). OSAC research and development needs. Retrieved from https://www.nist.gov/topics/organization-scientific-area-committees-forensic-science/osac-research-and-development-needs.

388. Spivak, H. M. (2017). Supporting forensic science is a priority at the National Institute of Justice. Retrieved from https://nij.gov/about/director/Pages/spivak-forensics.aspx.

389. U.S. Department of Justice (DOJ), Office of Justice Programs (OJP), National Institute of Justice (NIJ). (2018). Forensic Laboratory Needs Technology Working Group — Opening a new channel to improve forensics. Retrieved from https://www.nij.gov/topics/forensics/lab-operations/Pages/forensic-laboratory-needs-technology-working-group.aspx.

390. Butler, J. M. (2015). U.S. initiatives to strengthen forensic science & international standards in forensic DNA. *Forensic Science International: Genetics, 18*, 4-20. https://doi.org/10.1016/j.fsigen.2015.06.008.

391. Spivak, H. M. (2018). Supporting crime lab directors and the formation of the Forensic Laboratory Needs Technology Working Group. Press release. U.S. Department of Justice, National Institute of Justice: Retrieved from https://www.nij.gov/about/director/Pages/spivak-ascld-2018.aspx.

XIII. Appendices and Resources

A. Review of the National Academy of Sciences Report and Prior Needs Assessments

The National Research Council, National Academy of Sciences' *Strengthening Forensic Science in the United States: A Path Forward* [30]

In an effort to address the needs of the forensic science community, Congress appointed the National Institute of Justice (NIJ) to create an independent committee to undertake a study on the needs of the forensic community. This Committee on Identifying the Needs of the Forensic Science Community, overseen by the National Academy of Sciences (NAS), created a detailed plan for addressing those needs in its 2009 report, *Strengthening Forensic Science in the United States: A Path Forward* (the 2009 NAS report). [30]

Thirteen recommendations were also outlined in the 2009 NAS report, which informed the present report. Of note are the various educational and research needs highlighted in these recommendations, as well as accreditation, certification, contextual bias, and recommendations for the medical examiner and coroner community. Additionally, setting and advancing standards, as well as supporting accreditation of laboratories and certifications for personnel, were addressed in both the 2009 NAS report and throughout this report. There was a focus on the needs of medicolegal death investigation (MDI) in the 2009 NAS report, and MDI was likewise treated as a special area of interest and focus in the development of this report. Finally, this report also used the 2009 NAS report's recommendation to focus on the nexus between the forensic sciences and homeland security, treating this as another special area of interest.

Following the publication of the 2009 NAS report, the National Science Technology Council (NSTC) Committee on Science established a Subcommittee on Forensic Science (SoFS) that met from 2009 to 2012 and reviewed policies, procedures, and plans related to forensic science at the federal, state, and local levels. [32] The SoFS identified challenges and opportunities for addressing the 2009 NAS report's recommendations related to research and development; training, education, and ethics; accreditation and certification; and standards of practice, coordinated through five interagency working groups. In 2014, the NSTC published the report, *Strengthening the Forensic Sciences*, which provided an overview of the interagency work that examined accreditation, certification, and proficiency testing. [32]

In 2015, the National Academies of Sciences, Engineering, and Medicine released the NIJ-commissioned report *Support for Forensic Science Research: Improving the Scientific Role of the National Institute of Justice.* [31]) The 2015 NAS report found that NIJ had made considerable progress in meeting its mission to advance the forensic sciences. It noted that "NIJ has a unique and critical role" among the diverse federal agencies working to impact the progress of forensic science, because unlike other agencies, NIJ focuses on forensic science research and development. The 2015 NAS report affirmed that NIJ should continue on its current path and provide a plan for building on its progress by taking strategic steps to improve its "capacity to support high-quality forensic science research." The 2015 NAS report also found that the efforts of NIJ have: "(1) restored authority that is appropriate for a science agency and addressed some previous concerns about NIJ's independence; and (2) contributed to the building of a research infrastructure necessary to develop and sustain research that advances forensic science methods."

The 2009 NAS report also provided the opportunity to approach these recommendations broadly, and to recognize the changes in the vast forensic science community in initiatives related to accreditation, standardization, and the exploration of human factors and bias across multiple contexts and with a multifaceted approach. Many local, state, and federal agencies, including the U.S. Department of Justice (DOJ), have endeavored to incorporate the 2009 NAS report recommendations and, where appropriate, adjust their policy and practice accordingly. These changes and activities are evident in a variety of sources, including the Bureau of Justice Statistics (BJS) *Census of Publicly Funded Forensic Crime Laboratories, 2009,* which shows an increasing number of accredited crime laboratories and externally certified analysts over time, as well the National Science and Technology Council's 2014 report, *Strengthening the Forensic Sciences,* and the 2015 NAS report, *Support for Forensic Science Research: Improving the Scientific Role of the NIJ.* [3-5, 31-34]

The National Institute of Justice, *Forensic Sciences: Review of Status and Needs* [6]

NIJ, the National Institute of Standards and Technology's (NIST) Office of Law Enforcement Standards (OLES), and the American Society of Crime Laboratory Directors (ASCLD) held a joint workshop in 1997 to assess the current state of forensic laboratories, focusing specifically on needs related to training; technology transfer; methods of research, development, testing, and evaluation; and analytical services. This assessment found that there is an ongoing need in the forensic community to broaden the scope of training programs, and that it is essential for agencies to utilize aggressive and creative ways of obtaining funding for training programs. With regard to technology transfer, the assessment found that forming partnerships across the various levels of laboratories was critical, as was quick access to affordable and reliable technology. In the assessment of methods, research, development, testing, and evaluation, nine disciplines within the forensic sciences were identified and specifically considered. Among these disciplines, several common needs were identified, including needs for standardization, validation, and the creation of information databases — though the assessment acknowledged that a blanket standard would not suffice due to the different needs and techniques of individual disciplines. Finally, with respect to analytical services, once the needs of the client are understood, the forensic services necessary to meet those needs can be identified and prioritized.

The Bureau of Justice Statistics, ***Censuses of Publicly Funded Forensic Crime Laboratories***
[3, 4, 33, 97]

For 20 years BJS has periodically surveyed crime laboratories, adding new data to facilitate analysis of crime laboratories' attributes over time. The first Census of Publicly Funded Forensic Crime Laboratories (Census), funded by NIJ, was conducted in 1998 and focused on DNA capabilities. Subsequent iterations of this Census expanded the focus, providing a snapshot of laboratory capabilities and needs at different points in time while also allowing for some trend analysis on critical areas of concern, such as backlogged cases and operating budgets. BJS expanded the 2014 Census to include a pilot study of agencies that solely analyze digital and multimedia evidence in support of criminal investigations and prosecutions. BJS will use the results of this pilot study to inform future data collections directed toward criminal justice agencies that process digital forensic evidence. BJS plans to conduct the next iteration of the Census in 2020. The Census is the only national source of information on the functions, budget, workload, staffing, and accreditation of laboratories and certification of laboratory staff.

Additionally, BJS plans to add a module to its next Law Enforcement Management and Administrative Statistics (LEMAS) survey to begin initial analysis of what forensic services law enforcement agencies provide. From this initial analysis, BJS plans to evaluate next steps to best answer the questions of interest to the forensic science community.[20]

BJS also launched the first Census of Medical Examiner and Coroner Offices (CMEC) in 2004, a census of all publicly funded offices conducting MDI in the United States. BJS is coordinating with NIJ and the Office of Science and Technology Policy's (OSTP) MDI working group (MDI-WG) members to ensure the survey instrument accurately reflects current activities and initiatives in the MDI and forensic science communities since the 2009 NAS report. BJS plans to field the CMEC in 2019. The CMEC will gather information on the staffing, budgets, caseloads, resources, policies, and procedures of medical examiner and coroner offices.

State Needs Assessments [35, 36]

While previous needs assessments have been conducted at the federal level, it is important to recognize that states are beginning to conduct their own needs assessments, as state and local leaders may be best situated to identify site- and system-specific needs, in addition to troubleshooting and developing solutions for their greatest needs.

One such assessment was conducted by the National Forensic Science Technology Center at Florida International University (NFSTC@FIU) for the Wisconsin State Crime Laboratory Bureau. [36] The report found that both case submissions and turnaround times were increasing. In addition to assessing the needs of the laboratory, NFSTC@FIU provided recommendations to improve productivity and efficiency, as directed by Wisconsin's attorney general. The Wisconsin attorney general used the findings and recommendations from this needs assessment to support specific actions and budgetary requests to increase

[20] The Justice for All Reauthorization Act of 2016, Section 16.b.3.D, requires that the present Needs Assessment of Forensic Laboratories consider the BJS survey of forensic providers recommended by the National Commission of Forensic Science (NCFS). The NCFS recommended that the attorney general should direct BJS to create a proposal for the development of a nationally representative survey to determine forensic capabilities for those who write reports and offer testimony within federal, state, and local law enforcement agencies and for medical examiner and coroner offices.

the laboratory's capacity in response to its increasing workload. The Wisconsin attorney general also called on the state's governor and legislature to fund the core elements of the criminal justice system that lie outside of DOJ's budget — prosecutors, public defenders, and the court system — embodying a true systems-based approach. [35]

Project FORESIGHT Data [37]

Project FORESIGHT is a business-guided self-evaluation of forensic science laboratories across the globe, with the largest representation from U.S. publicly funded, accredited forensic laboratories.[21] The project was initially sponsored by NIJ (NIJ award numbers 2003-RC-CX-K001, 2008-DN-BX-K223, and 2010-D1-BX-K016). The Project FORESIGHT database — developed over the past decade from 2005-2017 — is maintained by the Center for Forensic Business Studies at West Virginia University's John Chambers College of Business and Economics. This database includes participating metropolitan, regional, state, and international laboratories with submissions of annual data from the past decade. Participating laboratories provide data for 18 different areas of investigation (e.g., DNA, fingerprints, drugs, toxicology) on casework, personnel, and detailed expenditures that correspond to their jurisdictions' fiscal year. [115] Laboratory managers can then use the FORESIGHT analysis to assess resource allocations, efficiencies, and value of services. The mission of Project FORESIGHT is to measure, preserve what works, and change what does not.

To support the DOJ Needs Assessment of Forensic Laboratories (NAFL), an analysis of existing Project FORESIGHT data was performed by Project FORESIGHT consultants using data from accredited U.S. local, regional, and state forensic laboratories for cases processed internally for the 2005-2006 reporting period through the 2016-2017 reporting period. As of 2018, 139 U.S. laboratory systems have contributed data to the project, which represents over 200 separate laboratory facilities. Of the 409 publicly funded crime laboratories identified in the 2014 BJS Census, 203 laboratories are Project FORESIGHT participants. Details regarding the data collected in Project FORESIGHT are outlined in the FORESIGHT literature. [182]

The key findings listed below are based on an analysis of existing Project FORESIGHT data, performed by Project FORESIGHT consultants who reviewed, verified, and validated relevant data, to offer technical and analytical support for this needs assessment of forensic laboratories located in the United States. [37] In addition to Project FORESIGHT data, this review is supplemented with data from the 2014 BJS Census, the FBI's Uniform Crime Reporting data, and U.S. Census Bureau data. Complete details of the Project FORESIGHT data analysis can be found in the NAFL Supplemental Materials.

Project FORESIGHT key findings:

- An analysis of the Project FORESIGHT laboratories' workloads and expenditures, representing a subset of publicly funded laboratories, estimates that there was a $640 million annual deficit for 2017 for forensic laboratories nationwide to reach an optimal balance of incoming laboratory requests and casework reported (workload inputs and

[21] For more information on Project FORESIGHT, visit the Project website https://business.wvu.edu/research-outreach/forensic-business-studies.

outputs) and maintain the ideal balance of capital investments and personnel. This estimate was achieved through the following assessment: an estimated $270 million was needed for all 139 laboratory systems that participated in FORESIGHT to reach an optimal balance of incoming laboratory requests and casework reported (workload inputs and outputs); and an estimated $50 million was needed for the FORESIGHT-participating laboratories to maintain the ideal balance of capital investments and personnel. Therefore, the combined budgetary deficiency for the FORESIGHT laboratories was approximately $320 million, which infers a minimum of a $640 million deficit for all forensic laboratories nationwide, since roughly half of the laboratories identified in the 2014 BJS Census are FORESIGHT participants.

- Turnaround time has grown dramatically in nearly every area of investigation over the last six years. The average area of investigation has seen a 60% increase in turnaround time, and some areas have had even more dramatic increases.
- The average 30-day backlog is growing faster than the growth in case submissions; the average backlog across all areas of forensic science has grown nearly 250% over the past six-year time period from 2011 to 2017.
- Efficiencies can be identified by determining the optimal mix of capital investment (including equipment), personnel expenditures, and consumables.
- In 2015 alone, laboratories expended over a quarter of a billion dollars to address the opioid crisis.
- Forensic laboratories as a collective group have a great incentive to sponsor further research into both the costs and the benefits of their contributions. Such information is informative to laboratory management in the internal allocation of scarce resources, as it measures the contributions made toward stated goals. Externally, return on investment (ROI) metrics are critical to policymakers in the allocation of scarce public resources across the seemingly limitless demands for funding. ROI metrics allow an easy comparison of the use of public funds.
- Research to date suggests that the level of productivity for any caseload is the most critical component for explaining efficiency in the laboratory.
  - Further deconstruction of the Project FORESIGHT data can offer each individual laboratory opportunities to significantly improve cost effectiveness and efficiencies by estimating the workforce needed to support any level of casework.
  - Workforce estimates can help laboratories better manage caseloads and provide jurisdictions with critical information when determining ways to expand the utilization of forensic evidence to the early stages of investigations and to more crime types, and when developing strategies to decrease laboratory turnaround times.
- U.S. forensic laboratory expenditures grew at a staggering rate in 2015 because of the opioid crisis. Growing expenditures for the analysis of drugs/controlled substances (37% increase) and toxicology (25% increase) contributed to an estimated $270 million spent by all U.S. laboratories in a single year (2015). For comparison, typical laboratory growth in expenditures had been less than 3% per year for the preceding decade. Between 2011 and 2017, the average turnaround time for drug/controlled substance casework grew from 58 days to 79 days (36% increase), and the average 30-day backlog grew from 385 to 1,250 cases (225% increase).

Because the Project FORESIGHT data and findings address the various themes of this report, they are referenced throughout. More information can be found in the NAFL Supplemental Materials [37].

B. Expanded Methodology for the Needs Assessment of Forensic Laboratories

Prior to engaging with stakeholders and representatives from crime laboratories and forensic science organizations, it was necessary to understand the current state of knowledge on the forensic science needs of crime laboratories, medical examiner and coroner offices, and the criminal justice system as a whole. To that end, this needs assessment began with a literature review considering not only the resources included in the 2016 Justice for All Reauthorization Act (JFARA) [1], but also other reports, documents, and the academic literature in an effort to be comprehensive and well-informed in the early stages of this assessment. More than 30 evaluations, assessments, and best practices documents from forensic laboratories, law enforcement agencies, medical examiner and coroner offices, academia, legal practitioners, court systems, and specific forensic science disciplines dating back to 1999 were included in the literature review. This review served to guide further assessment of the needs of forensic science service providers, and to identify gaps that may benefit from further research and evaluation. Additionally, the needs identified during the literature review helped set the framework for stakeholder listening sessions and systematically prioritize the content of the resulting report.

To guide the listening sessions, listening session participants (LSPs) and stakeholder contributors were given a list of reference materials and questions generated from the literature review. Several stakeholders contributed additional resources and follow-up materials after their listening sessions to help further inform this report. DOJ also performed targeted outreach to individuals and stakeholders to obtain additional details on programs and practices. LSPs were granted confidentiality to facilitate candid discussions. As such, all data have been analyzed and presented in aggregate form, with no individual attributions.

The data analysis for this needs assessment involved the identification of common themes extracted from the listening session notes, supported by other sources of literature and data. This thematic analysis involved looking for both commonalities in responses — for example, similarities in perceptions, challenges faced, and policy and procedures. The information collected from the listening sessions demonstrated the interconnectedness of the emergent themes in this needs assessment, providing insight into how these issues not only relate to each other, but also inform and condition other areas of consideration in the forensic sciences. As such, it is expected that there will be considerable overlap among the themes discussed in the analysis.

Thematic analysis of stakeholder listening sessions led to the emergence of nine distinct, yet often interrelated, themes: personnel, education, training and continuing education, human factors, workload, infrastructure and equipment, research and funding, systems-based approaches, and special or timely topics. Although treated as a separate theme, the value and utility of employing systems-based approaches were interwoven through the other eight themes that emerged. These thematic analyses, combined with numeric

data from numerous sources, also exploited a strength of the current study: the use of a mixed-methods, multidisciplinary approach to assessing the needs of a broad, multifaceted collection of stakeholders in the forensic sciences. The emergent themes from that analysis were then analyzed in light of the extant literature. These thematic analyses seek to incorporate the multiple voices and perspectives of the varied groups of stakeholders that all fall under the wide umbrella of the forensic sciences. The process of creating this report also involved incorporating findings from the literature, where appropriate, and identifying gaps in the existing literature.

This assessment used both quantitative and qualitative data to complement each other and present a more holistic, developed picture of the forensic sciences. Although it provides a snapshot in time, this is an approach that has not necessarily been available in previous assessments, nor has this information been available or compiled in a concise, organized format. This methodological approach was also a function of the timeline mandated by the JFARA legislation. No new data could have been collected in the timeframe provided. However, the approach chosen is a traditional methodology used to develop new data collection strategies, identify new and important variables, and specify variable measurement. As such, this assessment should be seen as a beginning, not an end.

C. Forensic Science Academic Degree Programs in the U.S.

Included in Table 10 below are the Forensic Science Education Programs Accreditation Commission (FEPAC)-accredited forensic science academic degree programs (see also Table 1), as well as other available programs that were identified through a state-by-state internet search for programs containing a forensic class or component. The results of this search were edited to reflect the academic topic areas significant to the present needs assessment. Any programs remaining were determined to have a sufficient forensic component to be listed as a forensic science academic degree program. This listing in no way reflects the merits of the programs, accreditation of their host institutions, enrollment and placement metrics, or other assessments of the programs or their content. This list is not intended to be all-encompassing; omission of any forensic science programs is the authors' oversight and does not reflect on any program's merit or the authors' personal viewpoints.

The methodology for developing this list replicated the approach of those researching the field. For example, it is most likely that prospective forensic science students would use a traditional internet research approach to discover more about programs at schools of interest, or more likely, schools in their geographic area. Therefore, the schools that were easiest to find on common search engines were included first. Following the compilation of that list, additional efforts were focused on finding programs with curricula that closely align with those of FEPAC-accredited programs. Programs lacking adequate information on available programs of study were not included in this list.

Additionally, it is important to note the inclusion of associate degree programs (e.g., Associate of Science [A.S.], Associate of Applied Science [A.A.S.]). For many roles in local forensic laboratories, particularly in rural areas, an associate degree is the minimum qualification for entry-level jobs. An associate degree in forensic science is designed to prepare students for technical positions in private or public agencies. These positions are designed specifically to fill roles in medical examiner offices, police departments, health departments, and other forensic laboratories. The associate degree programs focus on

teaching skills in crime scene investigation, death investigation, laboratory technology, and/or computer forensics. These programs differ from bachelor's or graduate degree options in a variety of ways; however, they are an important part of the forensic science education system.

One educational path not included in Table 10 is programs that offer a degree minor or specialization tracks in forensics and/or investigations as a way to support traditional science degrees, certificates, or other disciplines that can have forensic applications. Some examples of these programs can be seen at various universities, such as Methodist University's minor in Applied Forensic Science, Hamline University's minor in Forensic Science and Forensic Science certificate programs, and Marymount University's minor in Forensics and Criminal Investigations. An additional educational path that is not included in this table is certificate programs, such as the Forensic Document Examination Graduate Certificate offered at Eastern Tennessee State University, or the four forensic graduate certificate programs offered by University of Florida Health.

Table 10: List of Forensic Science Academic Degree Programs in the U.S. (alphabetical by state)

A program in bold indicates that the program was accredited by FEPAC as of April 2019.

State	University	Degree	Level
AL	Alabama State University	Forensic Chemistry	B.S.
AL	Alabama State University	Forensic Science	M.S.
AL	Auburn University	Entomology	M.S.
AL	Auburn University	Entomology	Ph.D.
AL	**University of Alabama Birmingham**	**Forensic Science**	**M.S.**
AZ	Arizona State University	Anthropology	B.A./B.S.
AZ	Arizona State University	Anthropology	Ph.D.
AZ	University of Arizona	Applied Archaeology	M.A.
AZ	University of Arizona	Anthropology	B.A./B.S.
AZ	University of Arizona	Anthropology	M.A.
AZ	University of Arizona	Anthropology	Ph.D.
AZ	University of Arizona	Entomology and Insect Science	M.S.
AZ	University of Arizona	Entomology and Insect Science	Ph.D. (minor)
AR	Arkansas State University	Crime Scene Investigation	A.A.S.
AR	Black River Technical College	Crime Scene Investigation	A.A.S.
AR	Pulaski Technical College	Crime Scene Investigation	A.A.S.
AR	University of Arkansas	Entomology	M.S.
AR	University of Arkansas	Entomology	Ph.D.
AR	University of Arkansas Community College Batesville	Crime Scene Investigation	A.A.S.
AR	University of Arkansas Community College Morrilton	Crime Scene Investigation	A.A.S.
CA	California State University—Chico	Anthropology	B.A.
CA	California State University—Chico	Forensic Anthropology	M.A.
CA	California State University—Chico	Entomology	B.S.
CA	California State University—Chico	Entomology	M.S.
CA	California State University—Chico	Entomology	Ph.D.
CA	California State University—East Bay	Biological Science, Forensic Science Concentration	B.S.
CA	California State University—East Bay	Chemistry, Forensic Science Concentration	B.S.
CA	California State University—Los Angeles	Anthropology	B.A.
CA	California State University—Los Angeles	Anthropology	M.A.
CA	California State University—Los Angeles	Criminalistics	M.S.
CA	Fresno City College	Forensic Evidence	A.S.

Table 10: List of Forensic Science Academic Degree Programs in the U.S. (alphabetical by state) (continued)

A program in bold indicates that the program was accredited by FEPAC as of April 2019.

State	University	Degree	Level
CA	National University	Forensic Sciences	M.A.
CA	Solano Community College	Criminal Justice—Computer Forensics	A.S.
CA	University of California—Davis	Forensic Science	M.S.
CA	University of California—Davis	Entomology—Forensic Entomology	B.S.
CA	University of California—Davis	Entomology	M.S.
CA	University of California—Davis	Entomology	Ph.D.
CA	University of California—Riverside	Entomology	B.A./B.S.
CA	University of California—Riverside	Entomology	M.S.
CA	University of California—Riverside	Entomology	Ph.D.
CA	University of California—Santa Cruz	Anthropology	Ph.D.
CT	Naugatuck Valley Community College	Criminal Justice—Computer Crime Deterrence	A.S.
CT	Naugatuck Valley Community College	Criminal Justice—Forensics	A.S.
CT	University of New Haven	Criminal Justice—Investigative Services	B.S.
CT	**University of New Haven**	**Forensic Science**	**B.S.**
CT	**University of New Haven**	**Forensic Science**	**M.S.**
CT	University of New Haven	Forensic Technology	M.S.
CT	University of New Haven	Investigations	M.S.
CO	Colorado State University	Entomology	M.S.
CO	Colorado State University	Entomology	Ph.D.
CO	Colorado State University	Anthropology with Concentrations in Archaeology, Biological Anthropology, and Cultural Anthropology	B.S.
CO	Metropolitan State University of Denver	Anthropology	B.A.
DE	University of Delaware	Insect Ecology and Conservation	B.S.
DE	University of Delaware	Entomology	M.S.
DE	University of Delaware	Entomology and Wildlife Ecology	Ph.D.
DC	**The George Washington University**	**Forensic Science—Concentrations in Forensic Chemistry, Molecular Biology, and Forensic Toxicology**	**M.S.**
DC	The George Washington University	Crime Scene Investigation	M.S.
DC	The George Washington University	Anthropology	B.A.

Table 10: List of Forensic Science Academic Degree Programs in the U.S. (alphabetical by state) (continued)

A program in bold indicates that the program was accredited by FEPAC as of April 2019.

State	University	Degree	Level
DC	The George Washington University	Anthropology	Ph.D.
FL	Florida A&M University	Agricultural Science with a Concentration in Entomology	M.S.
FL	Florida A&M University	Entomology—Cooperative program with the University of Florida	Ph.D.
FL	Florida Gulf Coast University	Forensic Studies	B.S.
FL	Florida Gulf Coast University	Forensic Science	B.S
FL	Florida Gulf Coast University	Anthropology	B.A.
FL	Florida Gulf Coast University	Forensic Studies	M.S.
FL	**Florida International University**	**Certificate in Forensic Science**	**B.S.**
FL	**Florida International University**	**Forensic Science**	**M.S.**
FL	Keiser University	Crime Scene Technology	A.S.
FL	Keiser University	Cyber Forensics/Information Security	B.S.
FL	Keiser University	Forensic Investigation	B.S.
FL	Palm Beach Atlantic University	Forensic Science	B.S.
FL	Saint Leo University	Criminal Justice—Crime Scene Investigation	M.S.
FL	Saint Leo University	Criminal Justice—Forensic Science	M.S.
FL	Saint Leo University	Criminalistics	B.A.
FL	**The University of Central Florida**	**Forensic Science**	**B.S.**
FL	**The University of Tampa**	**Forensic Science**	**B.S.**
FL	University of Florida	Entomology and Nematology	B.S.
FL	University of Florida	Entomology and Nematology	M.S.
FL	University of Florida	Entomology and Nematology	Ph.D.
FL	University of Florida—Gainesville	Forensic Anthropology	M.S.
FL	University of Florida—Gainesville	Forensic Anthropology	Ph.D.
FL	University of Florida Health	Forensic Medicine	M.S.
FL	University of South Florida	Anthropology	B.A.
FL	University of South Florida	Applied Anthropology—Archaeological and Forensic Science	M.A.
FL	University of South Florida	Applied Anthropology—Archaeological and Forensic Science	Ph.D.

Table 10: List of Forensic Science Academic Degree Programs in the U.S. (alphabetical by state) (continued)

A program in bold indicates that the program was accredited by FEPAC as of April 2019.

State	University	Degree	Level
FL	University of South Florida	Applied Anthropology—Bio-Cultural Medical	M.A.
FL	University of South Florida	Applied Anthropology—Bio-Cultural Medical	Ph.D.
GA	**Albany State University**	**Forensic Science**	**B.S.**
GA	Albany State University	Criminal Justice	B.S.
GA	Ogeechee Technical College	Criminal Justice Technology	A.A.S.
GA	Savannah State University	Forensic Science—Biology	B.S.
GA	Savannah State University	Forensic Science—Chemistry	B.S.
GA	University of North Georgia	Criminal Justice—Forensics	B.S.
HI	University of Hawaii at Manoa	Anthropology	B.A.
HI	University of Hawaii at Manoa	Anthropology	M.A.
HI	University of Hawaii at Manoa	Anthropology	Ph.D.
HI	University of Hawaii at Manoa	Entomology	M.S.
HI	University of Hawaii at Manoa	Entomology	Ph.D.
ID	University of Idaho	Entomology	B.S.
ID	University of Idaho	Entomology	M.S.
ID	University of Idaho	Entomology	Ph.D.
IL	Loyola University Chicago	Forensic Science	B.S.
IL	William Rainey Harper College	Forensic Science	A.A.S.
IL	Kishwaukee College	Criminal Justice—Forensic Tech	A.S.
IL	**University of Illinois at Chicago**	**Forensic Science**	**M.S.**
IL	**Loyola University at Chicago**	**Forensic Science**	**B.S.**
IN	**Indiana University—Purdue University—Indianapolis**	**Forensic Science and Investigative Sciences**	**B.S.**
IN	**Indiana University—Purdue University—Indianapolis**	**Forensic Science and Investigative Sciences**	**M.S.**
IN	University of Indianapolis	Anthropology	B.A.
IN	University of Indianapolis	Anthropology	M.S.
IN	Purdue University	Insect Biology	B.S.
IN	Purdue University	Entomology	M.S.
IN	Purdue University	Entomology	Ph.D.
IA	Iowa State University	Insect Science	B.S.
IA	Iowa State University	Entomology	M.S.
IA	Iowa State University	Entomology	Ph.D.

Table 10: List of Forensic Science Academic Degree Programs in the U.S. (alphabetical by state) (continued)

A program in bold indicates that the program was accredited by FEPAC as of April 2019.

State	University	Degree	Level
KS	Emporia State University	Forensic Science, Concentrations in Biology and Chemistry	M.S.
KS	Kansas State University	Entomology	Graduate Certificate
KS	Kansas State University	Entomology	M.S.
KS	Kansas State University	Entomology	Ph.D.
KS	Northwest Kansas Technical College	Crime Scene Investigation	A.A.S.
KS	University of Kansas	Entomology	M.A.
KS	University of Kansas	Entomology	Ph.D.
KS	Washburn University	Digital Forensics	B.A.
KS	Washburn University	Forensic Anthropology	B.S.
KS	Washburn University	Forensic Chemical Science	B.S.
KS	Washburn University	Forensic Investigation	B.A.
KY	**Eastern Kentucky University**	**Forensic Science, Chemistry and Biology Options**	**B.S.**
KY	**Eastern Kentucky University**	**Digital Forensics and Cybersecurity**	**B.S.**
KY	University of Kentucky	Entomology	B.S.
KY	University of Kentucky	Entomology	M.S.
KY	University of Kentucky	Entomology	Ph.D.
LA	Louisiana State University	Anthropology	B.A.
LA	Louisiana State University	Anthropology—Forensic Anthropology	M.A.
LA	Louisiana State University	Anthropology	Ph.D.
LA	Louisiana State University	Entomology	M.S.
LA	Louisiana State University	Entomology	Ph.D.
MA	Bay Path University	Cyber Security—Digital Forensics	B.S.
MA	Becker College	Criminal Justice	B.S.
MA	Boston University	Forensic Anthropology	M.S.
MA	**Boston University School of Medicine**	**Biomedical Forensic Science**	**M.S.**
MD	Loyola University Maryland	Forensic Studies	B.S.
MD	University of Baltimore	Forensic Studies	B.S.
MD	University of Maryland	Forensic Medicine	M.S.

Table 10: List of Forensic Science Academic Degree Programs in the U.S. (alphabetical by state) (continued)

A program in bold indicates that the program was accredited by FEPAC as of April 2019.

State	University	Degree	Level
MD	University of Maryland	Entomology	M.S.
MD	University of Maryland	Entomology	Ph.D.
MD	**Towson University**	**Forensic Chemistry**	**B.S.**
MD	**Towson University**	**Forensic Science**	**M.S.**
ME	Central Maine Community College	Forensic Science	A.A.S.
ME	University of Maine	Anthropology	B.A.
ME	University of Maine	Anthropology and Environmental Policy	M.A.
ME	University of Maine	Anthropology and Environmental Policy	Ph.D.
MI	Lake Superior State University	Criminal Justice—Criminalistics	B.S.
MI	Lake Superior State University	Forensic Chemistry	B.S.
MI	**Madonna University**	**Forensic Science**	**B.S.**
MI	Michigan State University	Anthropology	B.A./B.S.
MI	Michigan State University	Physical Anthropology—Forensic Anthropology	Ph.D.
MI	Michigan State University	Entomology—Forensic Entomology	B.S.
MI	Michigan State University	Entomology	M.S.
MI	Michigan State University	Entomology	Ph.D.
MI	**Michigan State University**	**Forensic Biology and Forensic Chemistry Tracks**	**M.S.**
MN	Hamline University	Anthropology	B.A.
MN	University of Minnesota	Entomology	M.S.
MN	University of Minnesota	Entomology	Ph.D.
MO	Maryville University of Saint Louis	Forensic Science	B.S.
MO	Missouri Western State University	Forensic Investigation	M.S.
MO	St. Louis University	Anthropology	B.A.
MO	University of Missouri	Entomology	M.S.
MO	University of Missouri	Entomology	Ph.D.
MS	Mississippi State University	Biochemistry with Concentrations in Forensic Science and Entomology	B.S.
MS	Mississippi State University	Agricultural Life Science with a Concentration in Entomology	M.S.
MS	Mississippi State University	Life Sciences with a Concentration in Entomology	Ph.D.
MS	**University of Mississippi**	**Forensic Chemistry**	**B.S.**

Table 10: List of Forensic Science Academic Degree Programs in the U.S. (alphabetical by state) (continued)

A program in bold indicates that the program was accredited by FEPAC as of April 2019.

State	University	Degree	Level
MS	University of Southern Mississippi	Forensic Science	M.S.
MS	University of Southern Mississippi	Forensics—Anthropology	B.S.
MS	University of Southern Mississippi	Forensics—Biological Sciences	B.S.
MS	University of Southern Mississippi	Forensics—Chemistry and Biochemistry	B.S.
MS	University of Southern Mississippi	Forensics—Criminal Justice	B.S.
MS	University of Southern Mississippi	Forensics—Physics	B.S.
MS	University of Southern Mississippi	Forensics—Polymer Science	B.S.
MT	Montana State University	Entomology	M.S.
MT	University of Montana	Anthropology with Forensic Anthropology	M.A.
NE	University of Nebraska—Lincoln	Insect Science—Science Option	B.S.
NE	University of Nebraska—Lincoln	Entomology	M.S.
NE	University of Nebraska—Lincoln	Entomology	Ph.D.
NV	University of Nevada, Reno	Anthropology	B.A.
NV	University of Nevada, Reno	Anthropology	M.A.
NV	University of Nevada, Reno	Anthropology	Ph.D.
NC	**Fayetteville State University**	**Forensic Biology**	**B.S.**
NC	Coastal Carolina Community College	Forensic Science	A.A.S.
NC	Johnston Community College	Criminal Justice Technology—Forensic Science	A.A.S.
NC	Methodist University	Applied Forensic Science	B.S.
NC	North Carolina State University	Anthropology	B.A.
NC	North Carolina State University	Biological Anthropology—Forensic Anthropology	M.A.
NC	North Carolina State University	Entomology	M.S.
NC	North Carolina State University	Entomology	Ph.D.
NC	Saint Augustine's University	Forensic Science	B.S.
NC	St. Andrews University	Forensic Science	B.A.
NC	Wake Technical Community College	Forensic Science	A.A.S.
NC	Wayne Community College	Criminal Justice Technology—Forensic Science	A.A.S.
NC	Western Carolina University	Forensic Anthropology	B.S.
NC	Western Carolina University	Forensic Science	B.S.
ND	North Dakota State University	Entomology	M.S.
ND	North Dakota State University	Entomology	Ph.D.
ND	University of North Dakota	Forensic Science	B.S.

Table 10: List of Forensic Science Academic Degree Programs in the U.S. (alphabetical by state) (continued)

A program in bold indicates that the program was accredited by FEPAC as of April 2019.

State	University	Degree	Level
NM	New Mexico State University	Agricultural Biology with a Concentration in Entomology	B.S.
NJ	The College of New Jersey	Forensic Chemistry	B.S.
NJ	Rutgers University	Entomology	B.S
NJ	Rutgers University	Entomology	M.S.
NJ	Rutgers University	Entomology	Ph.D.
NY	**Alfred State—SUNY College of Technology**	**Forensic Science Technology**	**B.S.**
NY	Binghamton University	Anthropology	B.A./B.S.
NY	Binghamton University	Anthropology	M.A.
NY	Binghamton University	Biomedical Anthropology	M.S.
NY	Binghamton University	Anthropology	Ph.D.
NY	**Buffalo State—SUNY**	**Forensic Chemistry**	**B.S.**
NY	Cornell University	Entomology	B.S.
NY	Cornell University	Entomology	M.S.
NY	Cornell University	Entomology	Ph.D.
NY	Utica College	Criminal Justice	B.S.
NY	CUNY John Jay College of Criminal Justice	Forensic Science	B.S.
NY	CUNY John Jay College of Criminal Justice	Digital Forensics and Cybersecurity	M.S.
NY	**CUNY John Jay College of Criminal Justice**	**Forensic Science**	**M.S.**
NY	State University of New York—Syracuse	Environmental and Forest Biology	M.S.
NY	State University of New York—Syracuse	Environmental and Forest Biology	M.P.S.
NY	State University of New York—Syracuse	Environmental and Forest Biology	Ph.D.
NY	Syracuse University	Forensic Science	B.S.
NY	Syracuse University	Forensic Science	M.S.
NY	**Syracuse University**	**Medicolegal Death Investigation**	**M.S.**
NY	St. Thomas Aquinas College	Forensic Science	B.S.
OH	Bowling Green State University	Forensic Investigation	B.S.
OH	Bowling Green State University	Forensic Science	M.S.
OH	Defiance College	Digital Forensics	B.S.
OH	Defiance College	Forensic Science	B.S.

Table 10: List of Forensic Science Academic Degree Programs in the U.S. (alphabetical by state) (continued)

A program in bold indicates that the program was accredited by FEPAC as of April 2019.

State	University	Degree	Level
OH	The Ohio State University	Anthropological Sciences	B.S.
OH	The Ohio State University	Anthropology	B.A.
OH	The Ohio State University	Anthropology	M.A.
OH	The Ohio State University	Anthropology	Ph.D.
OH	The Ohio State University	Entomology	B.S.
OH	The Ohio State University	Entomology	M.S.
OH	The Ohio State University	Entomology	Ph.D.
OH	**Ohio University**	**Forensic Chemistry**	**B.S.**
OH	The University of Findlay	Forensic Biology	B.S.
OH	The University of Findlay	Forensic Chemistry	B.S.
OH	Tiffin University	Criminalistics	B.S.
OH	Tiffin University	Digital Forensics	B.S.
OK	Oklahoma State University	Entomology, with a Bio-Forensics Option	B.S.
OK	Oklahoma State University	Entomology	M.S.
OK	Oklahoma State University	Entomology	Ph.D.
OK	**Oklahoma State University**	**Forensic Science—Forensic Toxicology and Forensic Biology Tracks**	**M.S.**
OK	**University of Central Oklahoma**	**Forensic Science—Chemistry and Molecular Biology**	**B.S.**
OK	**University of Central Oklahoma**	**Forensic Science—Digital Forensics**	**B.S.**
OR	Oregon State University	Crop Science, with a Concentration in Entomology	M.S.
OR	Oregon State University	Crop Science, with a Concentration in Entomology	Ph.D.
OR	Oregon State University	Horticulture, with a Concentration in Entomology	M.S.
OR	Oregon State University	Horticulture, with a Concentration in Entomology	Ph.D.
PA	**Arcadia University**	**Forensic Science**	**M.S.**
PA	**Cedar Crest College**	**Forensic Science and Genetic Engineering, Concentration in Forensic Science**	**B.S.**
PA	**Cedar Crest College**	**Forensic Science**	**M.S.**
PA	**Duquesne University**	**Forensic Science**	**M.S.**
PA	**The Pennsylvania State University**	**Forensic Science**	**B.S.**
PA	**The Pennsylvania State University**	**Forensic Science**	**M.P.S.**

Table 10: List of Forensic Science Academic Degree Programs in the U.S. (alphabetical by state) (continued)

A program in bold indicates that the program was accredited by FEPAC as of April 2019.

State	University	Degree	Level
PA	The Pennsylvania State University	Entomology	M.S.
PA	The Pennsylvania State University	Entomology	Ph.D.
PA	**West Chester University**	**Forensic and Toxicological Chemistry**	**B.S.**
PA	Drexel University College of Medicine	Forensic Science	M.S.
PA	Mercyhurst College	Bioanthropology	B.S.
PA	Mercyhurst College	Bioarchaeology	B.S.
PA	Mercyhurst College	Applied Forensic Sciences with Concentrations in Criminalistics/ Forensic Biology, Forensic Anthropology, and Forensic Chemistry	B.S.
PA	Mercyhurst College	Anthropology with Forensic and Biological Anthropology, Archaeology, and Geoarchaeology Tracks	M.S.
PA	Philadelphia College of Osteopathic Medicine	Forensic Medicine	M.S.
SC	Clemson University	Entomology	M.S.
SC	Clemson University	Entomology	Ph.D.
TN	Middle Tennessee State University	Anthropology	B.A./B.S.
TN	Middle Tennessee State University	Forensic Science	B.S.
TN	University of Tennessee	Entomology and Plant Pathology	M.S.
TN	University of Tennessee	Entomology, Plant Pathology, and Nematology	Ph.D.
TN	University of Tennessee	Anthropology with Disasters, Displacement and Human Rights, and Forensic Concentrations	B.A.
TN	University of Tennessee	Anthropology	M.A.
TN	University of Tennessee	Anthropology	Ph.D.
TN	University of Tennessee	Biological Anthropology—Forensic Anthropology	M.A.
TN	University of Tennessee	Biological Anthropology—Forensic Anthropology	Ph.D.
TX	**Sam Houston State University**	**Forensic Science**	**M.S.**
TX	Sam Houston State University	Forensic Science	Ph.D.
TX	St. Edward's University	Forensic Science	B.S.
TX	St. Mary's University	Forensic Science—Biology	B.S.
TX	St. Mary's University	Forensic Science—Chemistry	B.S.

Table 10: List of Forensic Science Academic Degree Programs in the U.S. (alphabetical by state) (continued)

A program in bold indicates that the program was accredited by FEPAC as of April 2019.

State	University	Degree	Level
TX	**Texas A&M University**	**Forensic and Investigative Sciences**	**B.S.**
TX	Texas A&M University	Forensic Entomology	B.S.
TX	Texas A&M University	Entomology	M.S.
TX	Texas A&M University	Entomology	Ph.D.
TX	Texas State University—San Marcos	Anthropology	B.A./B.S.
TX	Tarleton State University	Chemistry—Forensic Chemistry	B.S.
TX	**University of North Texas**	**Certificate Programs in Conjunction with Biochemistry, Biology, and Chemistry**	**B.S.**
TX	University of North Texas Health Science Center	Forensic Genetics	M.S.
TX	University of North Texas	Anthropology	B.A.
TX	University of North Texas	Anthropology	M.A./M.S.
VA	George Mason University	Anthropology	B.A.
VA	George Mason University	Forensic Science	B.S.
VA	George Mason University	Anthropology	M.A.
VA	George Mason University	Forensic Science	M.S.
VA	**Liberty University**	**Forensic Science**	**B.S.**
VA	Liberty University	Criminal Justice—Crime Scene Investigation	B.S.
VA	**Virginia Commonwealth University**	**Forensic Science**	**B.S.**
VA	**Virginia Commonwealth University**	**Forensic Science**	**M.S.**
VA	Virginia Commonwealth University	Anthropology	B.S.
VA	Virginia Tech University	Entomology	M.S.
VA	Virginia Tech University	Entomology	Ph.D.
VA	Radford University	Anthropological Sciences with a Concentration in Forensic Anthropology	B.S.
WA	Washington State University	Entomology	M.S.
WA	Washington State University	Entomology	Ph.D.
WV	Fairmont State University	Forensic Science	B.S.
WV	**Marshall University**	**Forensic Science, Emphasis in Digital Evidence**	**M.S.**
WV	**Marshall University**	**Forensic Science**	**M.S.**
WV	**West Virginia University**	**Forensic and Investigative Sciences**	**B.S.**

Table 10: List of Forensic Science Academic Degree Programs in the U.S. (alphabetical by state) (continued)

A program in bold indicates that the program was accredited by FEPAC as of April 2019.

State	University	Degree	Level
WV	West Virginia University	Forensic and Investigative Sciences	M.S.
WV	West Virginia University	Forensic Science	Ph.D.
WV	West Virginia University	Plant and Soil Sciences with a Concentration in Entomology	M.S.
WI	University of Wisconsin—Madison	Anthropology	B.A./B.S.
WI	University of Wisconsin—Madison	Anthropology with Concentrations in Archaeology, Biological Anthropology, and Sociocultural Anthropology	M.A./M.S.
WI	University of Wisconsin—Madison	Anthropology	Ph.D.
WI	University of Wisconsin—Madison	Entomology	B.S.
WI	University of Wisconsin—Madison	Entomology	M.S.
WI	University of Wisconsin—Madison	Entomology	Ph.D.
WY	University of Wyoming	Entomology	M.S.
WY	University of Wyoming	Entomology	Ph.D.

NCJ 253626